



**REVISED BENCH-SCALE AND PILOT-SCALE
TREATABILITY STUDY WORK PLAN
ELI LILLY & COMPANY**

**FOR THE PROPERTY LOCATED AT:
EVONIK DEGUSSA CORPORATION
TIPPECANOE LABORATORIES
1650 LILLY ROAD
LAFAYETTE, TIPPECANOE COUNTY, INDIANA**



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NEWFIELDS
2850 Lake Vista Drive, Suite 140
Lewisville, Texas 75067
Tel: (972) 956-9100 - Fax: (972) 956-9198
www.newfields.com

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ACRONYM AND ABBREVIATION SUMMARY

AST	aboveground storage tank
ASTM	American Society for Testing and Materials
bgs	below ground surface
BOD	biological oxygen demand
BTEX	benzene, toluene, ethylbenzene, and total xylenes
C ₆ H ₆	benzene
C ₆ H ₅ Cl	chlorobenzene
C ₄ H ₈ O	THF
C ₁₀ H ₁₅ N	n,n-DEA
CaO ₂	calcium peroxide
CAS No.	Chemical Abstracts Service Registry Number
CB	chlorobenzene
ClC ₆ H ₄ CF ₃	pCBT
CMS	Corrective Measure Study
CO ₂	carbon dioxide
COC	constituent of concern
COD	chemical oxygen demand
DO	dissolved oxygen
DTW	depth to water
EPC	end-point criteria
ERC	Environmental Restrictive Covenant
Evonik	Evonik Degussa Corporation
Fe	iron
Fe(II)	ferrous iron
Fe(III)	ferric iron
ft	feet
g/L	grams per liter
gpm	gallons per minute
HO ₂	perhydroxyl radical
H ₂ O ₂	hydrogen peroxide
ID	identification
ISCO	In-Situ Chemical Oxidation
KMnO ₄	potassium permanganate
Lilly	Eli Lilly and Company
mg/L	milligrams per liter
ml	milliliter
Mn ⁺²	manganese
MNA	monitored natural attenuation

ACRONYM AND ABBREVIATION SUMMARY (CONTINUED)

MnO ₂	manganese dioxide
MnO ₄ ⁻	permanganate
MSDS	Material Safety Data Sheets
msl	mean sea level
NaMnO ₄	sodium permanganate
NAPL	non-aqueous phase liquid
Na ₂ S ₂ O ₈	sodium persulfate
n,n-DEA	n,n-diethylaniline
O ₂	oxygen
O ₃	ozone
OH	hydroxide ion
ORC®	Oxygen Release Compound®
ORC-A®	Oxygen Release Compound – Advanced®
ORP	oxygen reduction potential
pCBT	p-chlorobenzotrifluoride
PID	photo-ionization detector
POC	point-of-compliance
ppm	parts per million
psi	pounds per square inch
QAPP	Quality Assurance Project Plan
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
S ₂ O ₈ ²⁻	persulfate
SDWA	Safe Drinking Water Act
Site	Tippecanoe Laboratories
SO ₄ ⁻	sulfate radical
SVOCs	semi-volatile organic compounds
THF	tetrahydrofuran
TOC	total organic carbon
TOD	total oxidant demand
µg/L	micrograms per liter
UIC	Underground Injection Control
USAF	U.S. Air Force
USCS	Unified Soil Classification System
U.S. EPA	United States Environmental Protection Agency
VOA	volatile organic analysis
VOCs	volatile organic compounds

1.0 INTRODUCTION

This Bench-Scale and Pilot-Scale Treatability Study Work Plan was developed as part of the Corrective Measure Study (CMS) process at the Evonik Degussa Corporation's (Evonik's) Tippecanoe Laboratories ("Site") located at 1650 Lilly Road in Lafayette, Tippecanoe County, Indiana [formerly owned and operated by Eli Lilly and Company (Lilly)]. Based on current Site conditions, the success of prior remedial measures, and evaluation of applicable remedial response measures; targeted spot treatment utilizing in-situ chemical oxidation (ISCO) followed by a bioenhanced natural attenuation program in three discrete "source" areas has been tentatively identified as appropriate for implementation of a remedial response. However, prior to implementation of the targeted spot treatment program, all parties agreed that Bench-Scale and Pilot-Scale Treatability Studies of various ISCO technologies were appropriate to further evaluate the approach proposed in the Revised CMS Report submitted on January 14, 2011. In addition, the bioenhanced natural attenuation program will be assessed as part of Pilot-Scale Treatability Study.

On November 21, 2011, Lilly submitted a Bench-Scale and Pilot-Scale Treatability Study Work Plan to the U.S. Environmental Protection Agency (U.S. EPA) for review. On February 17, 2012, U.S. EPA issued a comments memorandum to Lilly; therefore, this Work Plan has been modified to address comments included in the referenced memorandum.

1.1 SITE SETTING AND GEOLOGY

The Site is located at 1650 Lilly Road in Lafayette, Tippecanoe County, Indiana and was previously owned and operated by Lilly (see Figure 1). The Site and its Resource Conservation and Recovery Act (RCRA) permit were transferred to Evonik effective January 1, 2010. The Site has been developed with fermentation and chemical synthesis facilities for the manufacture of pharmaceutical and animal health products.

The Main Plant area of the Site is located on a plateau bounded by incised valleys on the north, south, and west created by the Wabash River and Big Wea Creek drainage features. The plateau, at an elevation of approximately 620 feet above mean sea level (msl), is over 100 feet above the Wabash River.

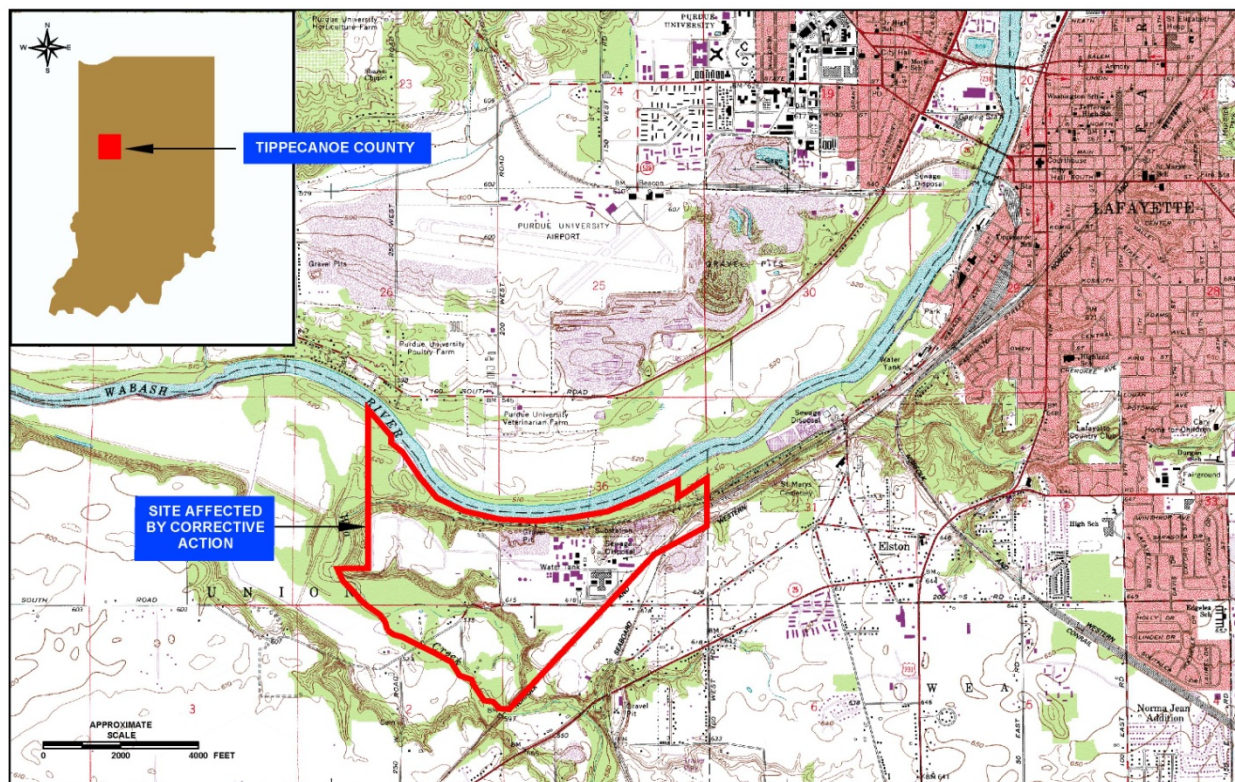


Figure 1 – Site Location

This section provides a general description of the geology and hydrogeology at the Site. A more detailed geologic description of the Site is provided in the Revised CMS Report, which was submitted to the U.S. EPA in January 2011, as well as previous investigation reports.

Figure 2 presents a cross-section that depicts the geology underlying the Main Plant. The bedrock surface is located approximately 220 feet below the ground surface (bgs) in the Main Plant area. An interval of sand and gravel, designated as Unit I is present beneath the Main Plant from the surface to a depth of approximately 65 feet bgs. Located beneath Unit I is a clayey till unit designated as Unit II that is up to 80 feet thick. Discontinuous lenses of fine silty sand have been described within Unit II. Unit II, which has been eroded away in both the Floodplain and the Wabash River drainage feature, is underlain by an interval of sand and gravel designated as Unit III that extends to the top of bedrock. Groundwater within the Unit I aquifer beneath the northern portion of the Main Plant flows in a northerly direction, discharges to the Unit IV

aquifer in the Floodplain, and then discharges to the Wabash River. Groundwater within the Unit I aquifer beneath the southern portion of the Main Plant flows in a southwesterly direction towards the Big Wea Creek drainage feature, and discharges to the Unit III aquifer.

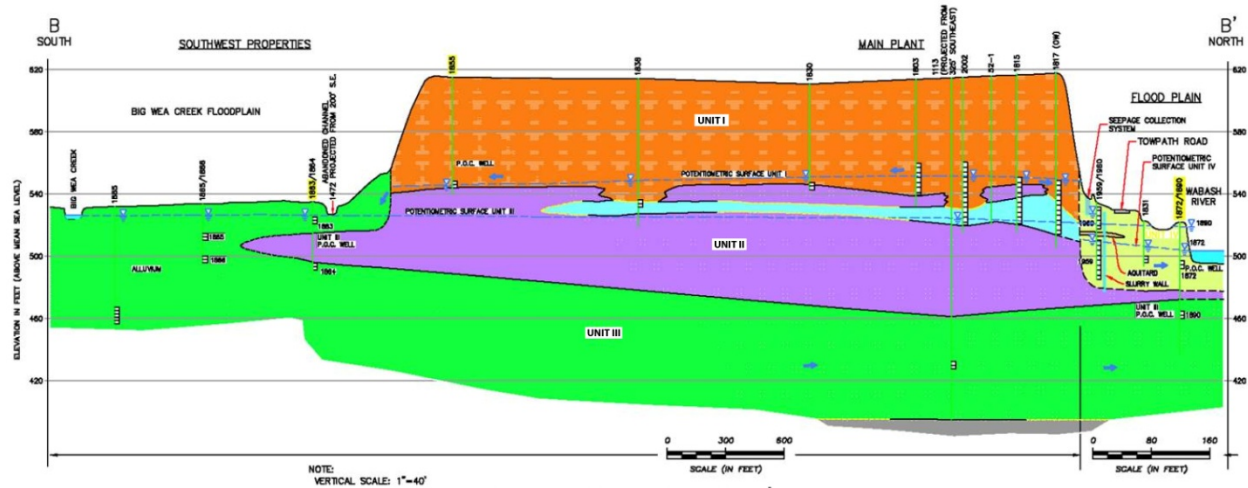


Figure 2 – Main Plant Cross-Section

The Floodplain is at an elevation of approximately 510 feet above msl, which is approximately 10 to 20 feet lower in elevation than the Big Wea Creek drainage feature. In the Floodplain, the sandy soils are intermixed with clayey deposits designated as Unit IV. Figure 3 presents a cross-section depicting the geology underlying the Floodplain adjacent to the Wabash River.

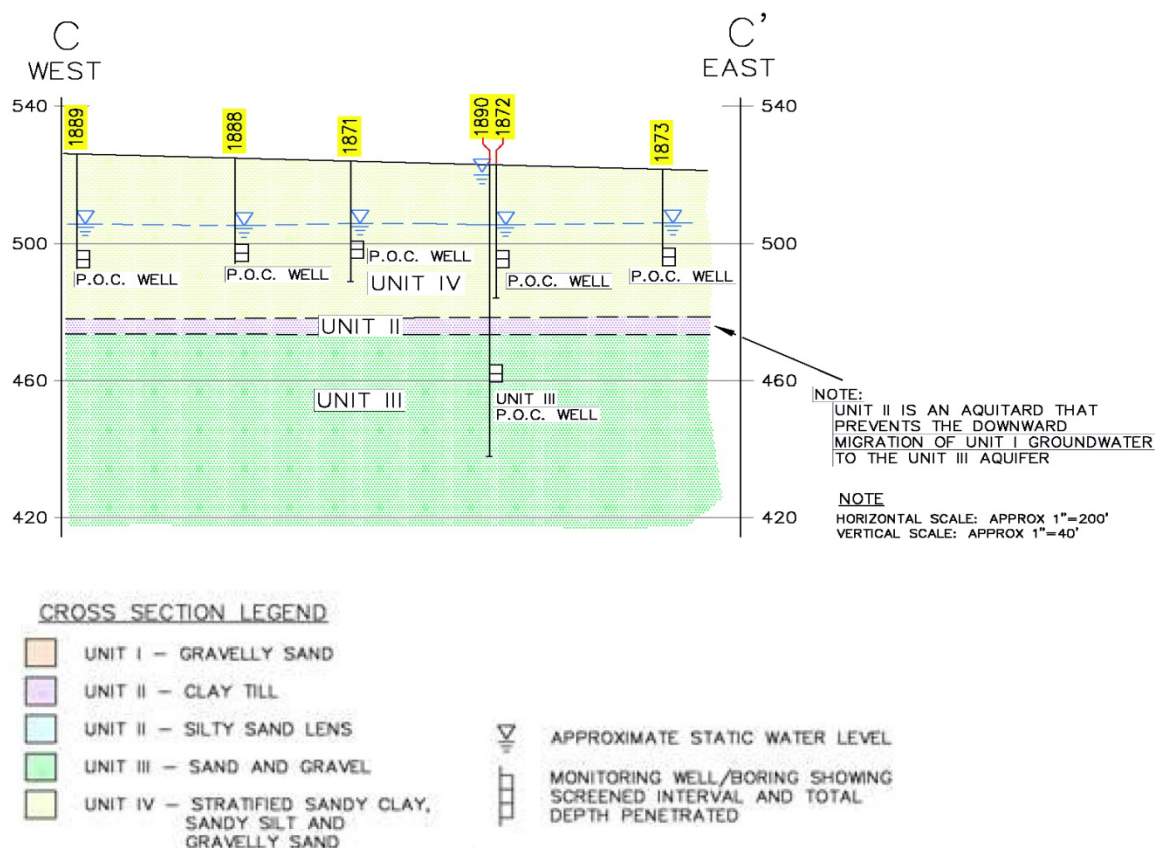


Figure 3 – Floodplain Cross-Section

As presented in the Revised CMS Report, several wells, including monitor well 1831, are located along the axis of a buried erosional feature on the upper surface of the Unit II aquitard in the Floodplain. Site assessment activities completed by Lilly during the 1980s revealed that the upper surface of the Unit II till aquitard is irregular and includes a buried erosional feature located under the bluff, north of the Main Plant and extending northward beneath the Floodplain (see the *Phase E Site Assessment Report* completed by Harza, 1989).

1.2 PROPOSED REMEDIAL APPROACH

Remediation of constituent of concern (COC) concentrations in groundwater using ISCO involves injecting chemical oxidants and potentially co-amendments directly into the saturated zone of the source area and hydraulically down-gradient portions of the COC plume. The chemical oxidants react with the COCs, eventually producing innocuous substances such as carbon dioxide and water; however, there may be chemical reaction steps required to reach those end points. In most cases, if an adequate oxidant dose is applied, the reactions proceed to completion, and the end products are reached quickly.

There are two main advantages of using ISCO over other conventional treatment technologies: large volumes of waste material are not usually generated, and treatment is commonly implemented over a much shorter time frame. Both of these advantages often result in savings on waste material disposal, monitoring, and maintenance.

ISCO has been used successfully to remove significant contaminant mass from saturated soils and groundwater at numerous sites for over two decades. Using a variety of oxidants, such as permanganate (MnO_4^-), hydrogen peroxide (H_2O_2), persulfate ($\text{S}_2\text{O}_8^{2-}$), iron (Fe – Fenton-driven, or H_2O_2 -driven), ozone (O_3), and proprietary products (i.e., RegenOxTM), success has been documented on a wide variety of COCs, including primary COCs at the Site. However, following a single application of an oxidant, rebound of dissolved COCs is typical. Therefore, it is common to perform multiple injections and/or follow these injections with injection of a bioremediation enhancement product to promote natural attenuation. Bioenhancement injection will be included within the Pilot-Scale Treatability Study, but will not be included within the Bench-Scale Treatability Study, since it may be very difficult to reproduce bioremediation activities in the laboratory that are representative of field conditions, due to the complexity of the chemicals and bioremediation processes involved.

As presented in the U.S. EPA ISCO Engineering Issue Paper published by Scott G. Huling and Bruce E. Pivetz, the following potential advantages and disadvantages of ISCO must be assessed prior to implementation:

Advantages

- ISCO is applicable to a wide range of contaminants.
- Contaminants are destroyed in-situ.
- In-situ treatment may reduce costs incurred by other technologies such as pump and treat, monitored natural attenuation (MNA), etc.
- Aqueous, sorbed, and non-aqueous phases of contaminants are transformed.
- There is enhanced mass transfer [enhanced desorption and non-aqueous phase liquid (NAPL) dissolution].
- Heat from H₂O₂ reactions enhances mass transfer, reaction rates, and microbial activity.
- ISCO potentially enhances post-oxidation microbial activity and natural attenuation.
- ISCO is typically cost competitive with other candidate technologies.
- ISCO is a relatively fast-acting treatment technology.

Disadvantages

- ISCO applications may incur oxidant delivery problems due to reactive transport and aquifer heterogeneities.
- Natural oxidant demand may be high in some soil/aquifers, resulting in inefficiency.
- Some oxidants have a short persistence due to fast reaction rates in the subsurface.
- There are health and safety issues regarding the handling of strong oxidants.
- There may be a potential for contaminant mobilization.
- There may be a potential for permeability reduction.
- There are limitations for application at heavily contaminated sites.
- Contaminant mixtures may require treatment trains.
- ISCO may have less oxidant/hydraulic control relative to other remedial technologies.

Complete and instant chemical oxidation of organic contaminants does not occur within the complex environment of the contaminated subsurface. Chemical oxidation is a sequential process taking the parent target contaminant through a series of partially oxidized intermediate daughter products on the path to complete oxidation. The oxidized intermediates formed are typically more biodegradable than the parent. Therefore, after completing implementation of an ISCO program, stimulation of in-situ bioremediation is commonly applied to promote natural attenuation of the remaining constituents. In-situ bioremediation through the use of an injected substrate has long been recognized as a very cost effective technology for achieving low contaminant concentrations when applied to dissolved-phase COC plumes. A variety of substances have been utilized to provide nutrients and energy sources to the existing microorganisms to enhance the bioremediation process. These substances may include gaseous air/oxygen, lactate, molasses, vegetable oil, nitrates, and/or proprietary products [i.e., Oxygen

Release Compound (ORC®)]. A combination of ISCO with bioenhanced natural attenuation has been tentatively selected as an appropriate remedial approach for the Site.

1.3 PRIMARY COCs

The five primary COCs at the Site are benzene, chlorobenzene (CB), p-chlorobenzotrifluoride (pCBT), tetrahydrofuran (THF), and n,n-diethylaniline (n,n-DEA); however, in addition to these COCs, additional volatile organic compounds (VOCs) are present within the plumes that will be treated. Therefore, the implementation of any treatment program must take into account the mass of these additional constituents and their potential impact on the effectiveness of the treatment program. Presented below is a summary of the five primary COCs. Additional information regarding potential biotreatment and MNA processes for the primary COCs was previously provided in the MNA Work Plan dated April 9, 2009.

Benzene	CAS No.:	71-43-2
	Composition:	C ₆ H ₆
	Description:	A natural constituent of crude oil that is a colorless and highly flammable liquid with a sweet smell and a relatively high melting point.
	Use:	Additive in gasoline, industrial solvent, precursor in the production of drugs, pesticides, plastics, synthetic rubber, and dyes.
	Fate:	Evaporates into the air very quickly. Dissolves slightly in water. Breaks down slowly in water and soil. Can pass through the soil into groundwater. Does not build up in plants or animals.

CB:	CAS No.:	108-90-7
	Composition:	C_6H_5Cl
	Description:	Colorless, flammable liquid with an aromatic, almond-like odor and a high boiling point.
	Use:	Common solvent and a widely used intermediate in the manufacture of other chemicals (such as herbicides, dyestuffs, and rubber). It was also once used in the manufacture of certain pesticides and the main precursor for the manufacture of phenol.
	Fate:	Readily evaporates into air. Some will dissolve in water. Broken-down rapidly by bacteria in soil. Does not build up in the food chain.
pCBT:	CAS No.:	98-56-6
	Composition:	$ClC_6H_4CF_3$
	Description:	Colorless liquid with a distinct aromatic odor.
	Use:	Used as an ink solvent the printing industry and as an intermediate in agrochemicals and pharmaceuticals.
	Fate:	Will preferentially partition to the atmosphere, due to its high volatility. The low solubility would limit its potential impact to aquatic systems. Will rapidly volatilize from dry and moist soils. Moderate level of bioaccumulation.
THF:	CAS No.:	109-99-9
	Composition:	C_4H_8O
	Description:	Colorless, water-miscible organic liquid with low viscosity at "room" (standard) temperature and pressure.
	Use:	Common solvent for polar reagents, can be used in hydroboration reactions to synthesize primary alcohols, and as a solvent for organometallic reactions such as organolithium and Grignard reactions. Can be used to dissolve rubber, plastics, and to degrease metal parts.
	Fate:	When released into the air, THF may be removed from the atmosphere to a moderate extent by wet deposition. When released into the soil, THF is expected to quickly evaporate. When released into water, THF may biodegrade to a moderate extent. Not expected to significantly bioaccumulate.

n,n-DEA: CAS No: 91-66-7
Composition: C₁₀H₁₅N
Description: It is a colorless to yellow liquid that is viscous and oily.
Commonly prepared by the ethylation of aniline.
Use: Uses include dyes, pharmaceuticals, pesticides, herbicides, and explosives.
Fate: Would become bound to soils due to high viscosity.
Slightly soluble in water.
Bioaccumulation may occur.

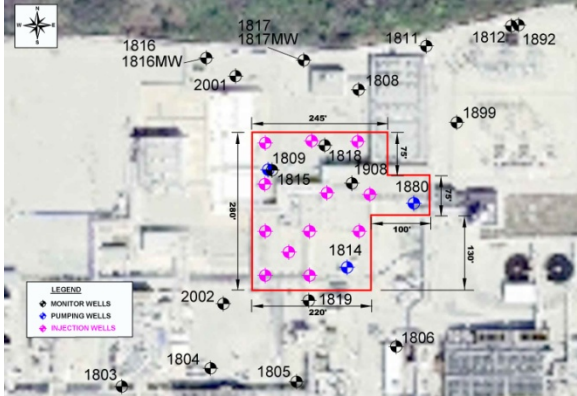
| 1.4 PRELIMINARY DESIGNS

Based on existing data and an evaluation completed and included in the Revised CMS Report, which was submitted to U.S. EPA in January 2011, the following preliminary designs were developed for the targeted spot treatment programs in the three separate “source” areas:

Note: The following preliminary designs are provided to depict the areas of treatment and the conceptual treatment approach. However, the final approach will be modified as appropriate based on the results of the Bench-Scale and Pilot-Scale Treatability Study.

1.4.1 Main Plant Source Area

There is no unacceptable risk associated with the current groundwater plume, as there are no complete exposure pathways to on-site workers, there is an Environmental Restrictive Covenant (ERC) in place to prevent future ingestion of the impacted groundwater, the ERC states that the property is not to be used for residential purposes, and there are facility procedures that provide worker protection during performance of any subsurface excavation activities. Therefore, within the Main Plant Source Area, the goal of the corrective measures is to provide additional assurance that end-point criteria (EPC) will not be exceeded at point-of-compliance (POC) wells in the future by providing the outlined remedial response for the area depicted in Figure 4.

<p>Injection Wells: 12 (pink)</p> <p>Extraction Wells: 3 (blue)</p> <p>Injected Chemical #1: RegenOx™</p> <p>Injection Events: Event 1 – 28,000 pounds Event 2 – 28,000 pounds Event 3 – 28,000 pounds</p> <p>Injected Chemical #2: ORC Advanced®</p> <p>Injection Event: Event 4 – 7,700 pounds</p> <p>Total Events: 4</p> <p>Extraction Well: During Injection Events</p> <p>Treatment: RegenOx™ Every 4 weeks ORC Advanced® (ORC-A® – 4 weeks after Event 3 Recovered groundwater treatment at existing water treatment plant</p>	 <p>Figure 4 – Main Plant Source Area Preliminary Design</p>
Monitoring:	Nine Wells (1808, 1809, 1814, 1815, 1818, 1819, 1908, 2001 and 2002) Quarterly during active treatment for one year and annually for a maximum of an additional two years to monitor for rebound.

1.4.2 1831 Floodplain Source Area

There is no unacceptable risk associated with the current groundwater plume, as there are no complete exposure pathways to on-site workers, there is an ERC in place to prevent future ingestion of the impacted groundwater, the ERC states that the property is not to be used for residential purposes, and there are facility procedures that provide worker protection during performance of any subsurface excavation activities. Therefore, the goal of the corrective measures in this localized area is to reduce contaminant mass to a degree such that it can be shown that POC EPC will not be exceeded in down-gradient POC wells in the future by providing the outlined remedial response for the area depicted in Figure 5.


<p>Injection Points: 14</p> <p>Injected Chemical: RegenOx™ (Part A) / ORC-A®</p> <p>Injection Event: 1,000 / 2,200 pounds</p> <p>Total Events: 1</p> <p>Monitoring: Seven wells (1822, 1831, 1833, 1870, 1872, 1876, and a new well)</p> <p>Semi-annually for one year and annually for a maximum of an additional two years to monitor for rebound.</p>	
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Figure 5 – 1831 Floodplain Source Area Preliminary Design

1.4.3 1855 Source Area

There is no unacceptable risk associated with the current groundwater plume, as there are no complete exposure pathways to on-site workers, there is an ERC in place to prevent future ingestion of the impacted groundwater, the ERC states that the property is not to be used for residential purposes, and there are facility procedures that provide worker protection during performance of any subsurface excavation activities. Therefore, the goal of the corrective measure in this area is to reduce pCBT concentrations up-gradient of POC monitor well 1855 and to reduce the pCBT concentration within POC monitor well 1855 to a concentration below the pCBT EPC by providing the outlined remedial response for the area depicted in Figure 6.

Injection Points:	36
Injected Chemical:	RegenOx™ (Part A) / ORC-A®
Injection Event:	675 pounds / 1,350 pounds
Total Events:	1
Monitoring:	Seven wells (1837, 1855, 2010, 2011, 2012, 2013, and 2014) Semi-annually during treatment for one year and annually for a maximum of an additional two years to monitor for rebound.



**Figure 6 – 1855 Source Area
Preliminary Design**

1.5 OBJECTIVE

The objectives of the Bench-Scale and Pilot-Scale Treatability Study include:

- Determine the ability of various chemical oxidants to successfully treat COCs present in saturated Site soils and groundwater.
- Determine if treatment by various chemical oxidants will create undesirable side products or mobilize metals.
- Select an effective chemical oxidant and identify the dosages necessary to accomplish the overall remedial objective.
- Assess the benefit of a bioenhancement injection program within the three source areas.

Additionally, a supplemental soil characterization of the 1855 Source Area is recommended to be conducted concurrent with field activities associated with the Bench-Scale Treatability Study. This supplemental soil characterization will provide additional information to be used in the final remedial design for the 1855 Source Area.

2.0 SUPPLEMENTAL SOIL CHARACTERIZATION

In 1999, piping, tanks, and equipment associated with the production of Treflan were included within a demolition project. This demolition project included the T60 area, including the former pCBT aboveground storage tank (AST). As part of the on-going groundwater monitoring program, a gradual increase in the pCBT concentration in Unit I POC monitor well 1855 was observed between 2005 and 2010, with recent concentrations decreasing to below the POC EPC. In late 2009, the following activities were performed to locate the source of the increasing pCBT concentrations at monitor well 1855:

- Review of aerial photographs identified soil piles located hydraulically up-gradient of monitor well 1855 dating back to approximately 2005. Analytical laboratory results of soil samples collected from 10 random locations within the soil piles reported below laboratory detection limits for pCBT. These results confirm that the dissolved-phase pCBT groundwater concentrations were likely not derived from the soil piles.
- Review of historic aerial photographs identified a disturbed soil area in 1998. Further research confirmed that this area was associated with fill material utilized to fill a low spot north of monitor well 1837. Analytical laboratory results of soil samples collected from eight random locations within this soil fill area reported below laboratory detection limits for pCBT. These results confirm that the dissolved-phase pCBT groundwater concentrations were likely not derived from the soil fill area.
- Five new groundwater monitor wells were installed hydraulically up-gradient of monitor well 1855 to further assess this area. Groundwater analytical laboratory results confirmed the presence of elevated pCBT concentrations hydraulically up-gradient of monitor well 1855. The pCBT concentrations were higher in the samples collected closer to the T60 area, and decreased by more than one order of magnitude in the groundwater sample collected hydraulically up-gradient (northeast) of the T-60 area.

Based on the soil and groundwater analytical laboratory results (i.e., monitor wells 1837, 1855, 1836, 1856, 2010, 2011, 2012, 2013, and 2014), it appears that the former T60 area is likely the source of the southwestern pCBT plume.

Prior to design of the final remedy and implementation of the remedial response, it is critical to adequately define the source area and ensure that the area projected for treatment will not become impacted in the future by migration of pCBT from an untreated hydraulically up-gradient source area.

2.1 SITE INVESTIGATION ACTIVITIES

A total of seven soil borings will be installed to obtain additional information regarding the likely pCBT source area and to assess whether soils within this area have the potential to continue to provide a pCBT source to the Unit I groundwater system. Figure 7 presents proposed investigation locations relative to historic site features and the Q4-2009 pCBT plume.

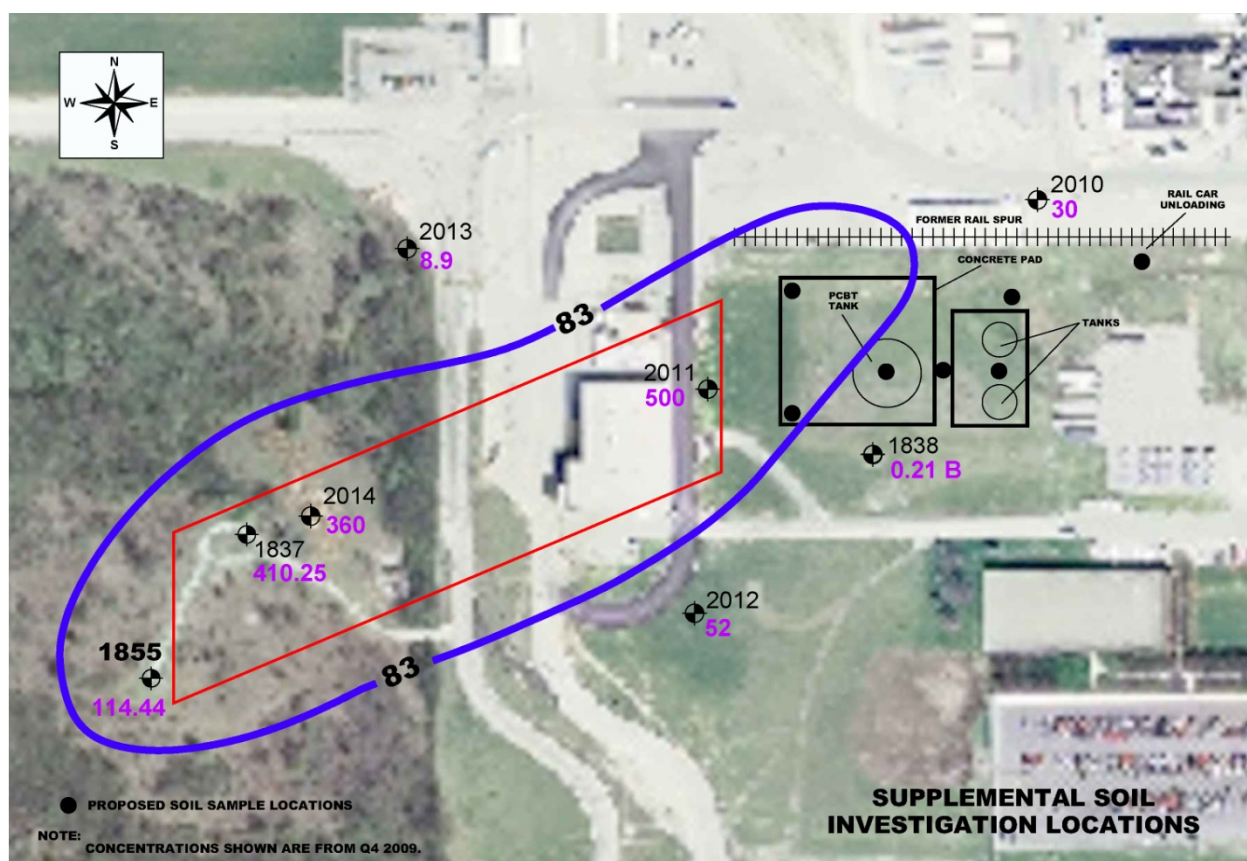


Figure 7 – 1855 Source Area Supplemental Soil Investigation Locations

2.1.1 Investigation Location and Utility Clearance

Prior to initiation of subsurface field activities, a site reconnaissance will be completed to stake and clear the proposed investigation locations. After location staking, Evonik will be contacted to identify subsurface utilities located in the investigation area.

2.1.2 Soil Boring Installation

Soil borings will be advanced with a truck-mounted, hollow-stem auger drilling rig with 4-inch inside diameter augers, or a sonic rig. Soil samples will be collected continuously from the ground surface to the base of Unit I, estimated to be 70 feet bgs.

Some of the soil borings are proposed to be advanced through the synthetic “capped” area; therefore, prior to piercing the cap, a portion of the cap will be removed and upon completion of investigation activities, the removed cap material will be replaced to maintain the integrity of the cap.

Once the soil samples are aboveground, soils will be described according to the Unified Soil Classification System (USCS), equivalent to ASTM D2488. In addition, a portion of each soil sample will be placed into individual Ziploc bags and the headspace gas will be monitored with a photo-ionization detector (PID). This field screening technique, along with visual and olfactory observations of the soil, will be utilized to select soil samples for chemical analyses. It is anticipated that a maximum of four soil samples will be collected from each soil boring (three from depths indicating the highest potential to contain pCBT concentrations in the vadose zone, and one soil sample from within the saturated zone immediately above the base of the Unit I water-bearing unit). Documented observations of the soil samples will consist of sample depth, lithology, color, structure, staining, degree of sample saturation, and the presence or absence of odors. An Indiana-Licensed Professional Geologist (LPG) will sign off on the geologic boring logs.

After completing soil sample collection, the inner rod of the augers will be removed and the soil boring will be plugged and abandoned concurrent with auger removal. Plugging and abandonment of the soil borings will be performed in accordance with Indiana regulations. After reaching ground surface, the “cap” material will be replaced, soil cover will be placed over the “cap” material, and the area will be re-vegetated.

2.1.3 Analytical Laboratory Testing

Soil samples will be placed into laboratory provided sample containers and labeled with the following information: location, identification (ID) number, container number, depth (soil), date, time, and sampling personnel. This information will also be entered on a chain-of-custody form. Soil samples will be placed into a cooler and chilled to a temperature of approximately 4°C for shipment to Heritage Environmental Services, LLC laboratory in Indianapolis, Indiana for analysis of VOCs by U.S. EPA Test Method 8260 and semi-volatile organic compounds (SVOCs) by U.S. EPA Test Method 8270.

2.1.4 Decontamination and Field Derived Waste

Drilling and sampling equipment will be decontaminated prior to the initiation of subsurface investigation activities. To ensure proper decontamination, soil samplers will be scrubbed with a non-phosphate detergent and distilled water wash, rinsed again with distilled water, and then allowed to air dry before being reused.

3.0 BENCH-SCALE TREATABILITY STUDY

Prior to implementation of a Pilot-Scale Treatability Study or full-scale implementation of a remedial approach, it is beneficial to perform a Bench-Scale Treatability Study to confirm that the primary COCs can be effectively treated by oxidative treatments. The results of the Bench-Scale Treatability Study will then be validated through implementation of an on-Site Pilot-Scale Treatability Study.

3.1 INTRODUCTION

A Bench-Scale Treatability Study assesses the treatability of the COCs, defines potential chemical reactions (adverse or desired) when the reaction occurs, and allows estimation of degradation rates. It is likely that the Bench-Scale Treatability Study will overestimate both the contaminant and oxidant degradation rates due to mixing and continuous contact in a closed system. However, rates obtained in the laboratory will provide useful information about relative COC degradation rates and the relative longevity of the oxidant that can be used in the Pilot-Scale Treatability Study.

Components of the bench-scale reactor should include the aquifer material (soil and water) since it will contain the majority of the contaminant(s) and other parameters that will largely influence oxidant demand and the success or failure of the treatment process.

3.1.1 Main Plant Source Area

As the first step in the Bench-Scale Treatability Study Testing program, soil samples will be collected through the utilization of a hollow-stem auger or sonic drill rig from two locations within the Main Plant Source Area. One location will be located north of monitor well 1814 and the second location will be located southeast of monitor well 1815 (see orange locations presented on Figure 8). Soil boring logs for 1814 and 1815 are provided in Attachment 1. In addition to the 5-foot soil samples collected from each soil boring with a continuous split spoon sampler, as shown in the following data summary, a groundwater sample will be collected from the two new locations after well completion.

<u>Well ID</u>	<u>Screened Interval (ft. bgs)</u>	<u>DTW (ft. bgs)</u>	<u>Saturated Soil Type</u>	<u>Proposed Soil Sample Interval</u>
1814	55 – 67	61	Fine Sand with Gravel	62 – 67
1815	66 – 96	64	Gravelly Sand	65 – 70

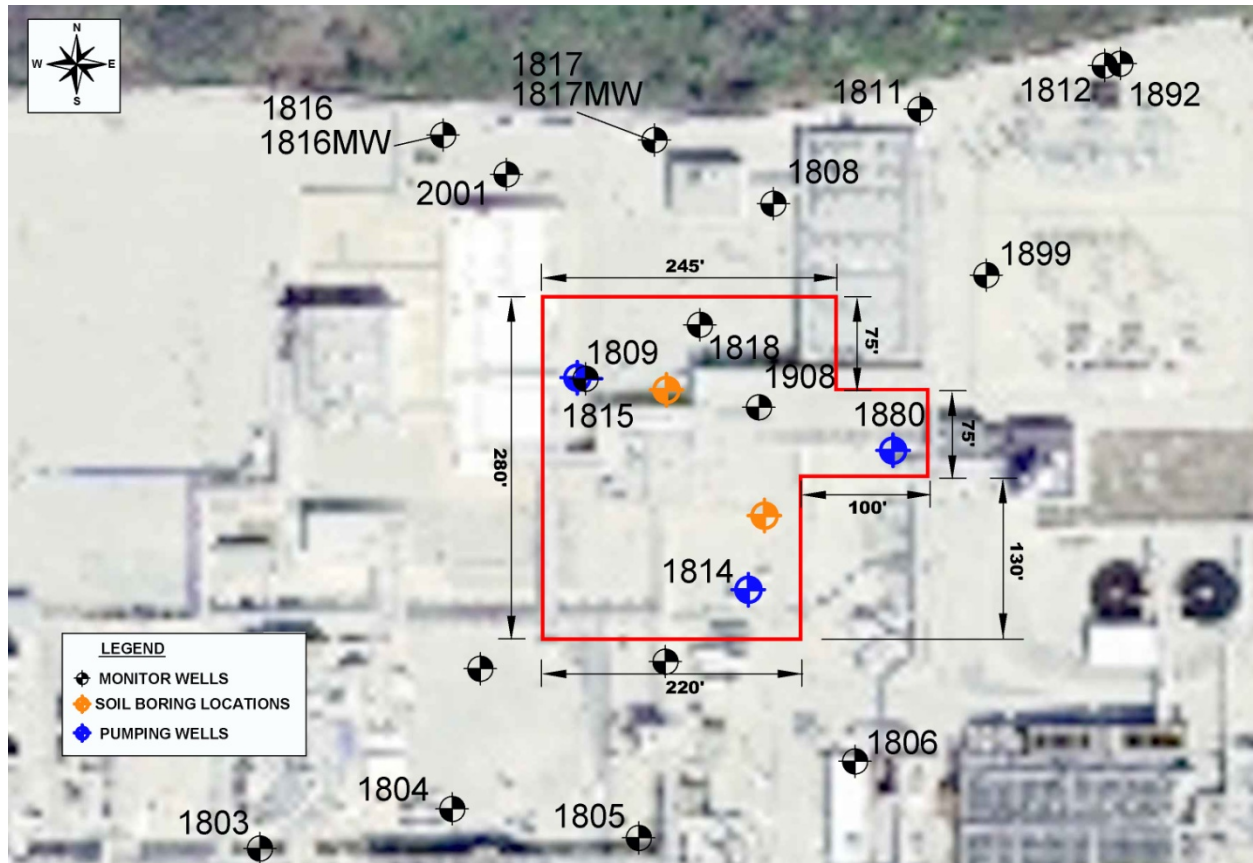


Figure 8 – Main Plant Source Area Bench-Scale Sample Locations

3.1.2 1855 Source Area

As the first step in the Bench-Scale Treatability Study testing program, soil samples will be collected through the utilization of a hollow-stem auger drill rig from five locations in the 1855 source area. Three of these locations will be at the up-gradient edge of the 1855 treatment area (see orange locations presented on Figure 9) and will be utilized as injection points during the Pilot-Scale Treatability Study. The other two locations (NMW-1 and NMW-2) will be

approximately 30 feet and 60 feet down-gradient from the three pilot injection wells, and will be utilized as monitoring points during the Pilot-Scale Treatability Study. The soil samples from the five boring locations may be composited in the laboratory if the volume of soil collected is not adequate to run multiple bench-scale tests. In addition to the 2-foot soil samples collected from each soil boring with a continuous split spoon sampler, as shown in the following data summary, a groundwater sample will be collected from the five new locations after well completion.

<u>Well ID</u>	<u>Screened Interval (ft. bgs)</u>	<u>DTW (ft. bgs)</u>	<u>Saturated Soil Type</u>	<u>Proposed Soil Sample Interval</u>
2011	63 – 68	65	Sand and Gravel	68 – 70



Figure 9 – 1855 Source Area Bench-Scale Sample Locations

3.1.3 1831 Floodplain Source Area

As the first step in the Bench-Scale Treatability Study testing program, soil samples will be collected through the utilization of a hollow-stem auger drill rig or direct-push rig from one location in close proximity to monitor well 1831 (see Figure 10). The soil boring log for monitor well 1831 is provided in Attachment 1. In addition to the three 5-foot soil samples collected from the soil boring as shown in the following data summary, a groundwater sample will be collected from monitor well 1831.

<u>Well ID</u>	<u>Screened Interval (ft. bgs)</u>	<u>DTW (ft. bgs)</u>	<u>Saturated Soil Type</u>	<u>Proposed Soil Sample Interval</u>
1831	23 – 28	8.75	Clayey Sand Silty Clay Silty Sand	9 – 14 16 – 21 24 – 29



Figure 10 – 1831 Floodplain Source Area Bench-Scale Sample Locations

3.2 SAMPLE COLLECTION PROCEDURES

3.2.1 Soil Sample Collection Procedures

3.2.1.1 Investigation Location and Utility Clearance

Prior to initiation of subsurface field activities, a site reconnaissance will be completed to stake and clear the proposed investigation locations. After location staking, Evonik will be contacted to identify subsurface utilities located in investigation area and requested to provide additional support, as required.

3.2.1.2 Soil Boring and Well Installation

Soil borings will be advanced with a truck-mounted, hollow-stem auger drilling rig with 4-inch inside diameter augers, a sonic rig, or a direct-push rig (within the floodplain area). Once the soil samples from the identified intervals are aboveground, approximately five kilograms of soils will be sealed into individual air-tight baggies. Each soil-containing baggie will be labeled with the following information: location, ID number, container number, depth (soil), date, time, and sampling personnel. This information will also be entered on a chain-of-custody form. Soil samples will be placed into a cooler and chilled to a temperature of approximately 4°C for shipment to a laboratory for performance of bench-scale testing.

For borings advanced with the hollow-stem auger drilling rig, the inner rod of the augers will be removed after reaching the soil boring target depth and well completion procedures will commence. Future injection and monitor wells will be constructed by installing screen across the entire Unit I saturated interval, based on historic data and field observations. Wells will be completed with 0.040-inch slotted, 2-inch diameter, Schedule 40, flush threaded polyvinyl chloride (PVC) screen; and 2-inch diameter, Schedule 40, flush threaded PVC casing to extend the well to ground surface.

Upon completion of well casing and screen installation, filter pack will be placed within the annular space between the injection/monitor well casing and screen and the hollow-stem augers to a height of approximately two feet above the screened interval. Concurrent with filter pack installation, the augers will be removed. This completion procedure will ensure that filter pack will be appropriately placed in the well completion. Thereafter, approximately two feet of granular bentonite will be installed above the filter pack and a cement/bentonite grout will be installed from the bentonite seal to the base of the locking-cap assembly. The well will then be completed within flush-mounted well completions, slightly elevated from the surrounding paved surfaces.

The following information will be entered into the well construction log:

- Project name;
- Project location;
- Drilling subcontractor;
- Field representative;
- Well identification;
- Date installed;
- Completion materials and corresponding depths (bgs);
- Top-of-casing and ground level elevations; and,
- Surface completion.

After the cement and concrete are allowed to cure for approximately 24 hours, well development activities will commence. Development activities will continue until developed water is relatively free of suspended sediment and field pH, specific conductance, and temperature measurements are equilibrated. Upon well completion, an Indiana-licensed public land surveyor will be retained to survey well coordinates and top-of-casing elevation for the newly installed wells.

For the boring advanced with a direct-push drilling rig in the Floodplain, after completing soil sample collection, the soil boring will be plugged and abandoned. Plugging and abandonment of the soil boring will be performed in accordance with Indiana regulations.

3.2.1.3 Soil Analytical Laboratory Testing

In addition to the soil samples retained for the Bench-Scale Treatability Study, a portion of soil from each sample interval will be placed into laboratory provided sample containers and labeled with the following information: location, ID number, container number, depth (soil), date, time, and sampling personnel. This information will also be entered on a chain-of-custody form. Soil samples will be placed into a cooler and chilled to a temperature of approximately 4°C for shipment to a Heritage Environmental Services, LLC laboratory in Indianapolis, Indiana for analysis of VOCs by U.S. EPA Test Method 8260, SVOCs by U.S. EPA Test Method 8270, Total RCRA Metals (metals) by U.S. EPA Test Method 6010/7000, and total organic carbon (TOC) by U.S. EPA Test Method 9060.

3.2.1.4 Decontamination and Field Derived Waste

Drilling and sampling equipment will be decontaminated prior to the initiation of subsurface investigation activities. To ensure proper decontamination, soil samplers will be scrubbed with a non-phosphate detergent and distilled water wash, rinsed again with distilled water, and then allowed to air dry before being reused.

3.2.2 Groundwater Sample Collection Procedures

Groundwater samples will be collected in accordance with the Groundwater Quality Assurance Project Plan (QAPP) Revision 3, dated May 2010. Approximately 12 liters of water will be collected from the two newly installed wells in the Main Plant Source Area, and the five newly installed wells in the 1855 Source Area. Samples should be placed into individual 1-liter containers supplied by the laboratory that have a septum seal on the top. Sample containers should be filled to the top with a meniscus bulge to prevent the potential accumulation of air in the jar and volatilization of contaminants during transport. Note that since there are three soil sample intervals within the 1831 Floodplain Source Area, there would need to be a total of 36 liters of water collected from monitor well 1831, which will be forward for bench-scale testing.

In addition to the groundwater samples retained for the Bench-Scale Treatability Study, split groundwater samples will be placed into laboratory provided sample containers and labeled with the following information: location, ID number, container number, date, time, and sampling personnel. This information will also be entered on a chain-of-custody form. At the end of the

sampling efforts, the split sample and the chain-of-custody form will be transported to Heritage Environmental Services, LLC laboratory in Indianapolis, Indiana for analysis of VOCs by U.S. EPA Test Method 8260, SVOCs by U.S. EPA Test Method 8270, and Total RCRA Metals (metals) by U.S. EPA Test Method 6010/7000.

3.3 OXIDANT IDENTIFICATION

Information contained within the referenced documents was used to identify the following oxidants that would be applicable to Site COC treatment [U.S. EPA, Huling and Pivetz; Regenis, and U.S. Air Force (USAF)]:

Permanganate Contaminant oxidation by MnO_4^- occurs by electron transfer rather than through the rapid H_2O_2 reaction and radical attack characteristic of Fenton oxidation. Presented below is a summary of advantages and disadvantages:

Advantages:

- Relatively slow reaction rate of MnO_4^- in subsurface systems, allowing for greater transport distances of MnO_4^- during injection delivery in medium and high permeability materials.
- MnO_4^- generally persists in the subsurface for months; however, persistence varies based on the concentration and volume of oxidant injected and from site to site.
- The long-term persistence of MnO_4^- contributes to diffusive transport of the oxidant into low-permeability materials, such as silty clay.
- Sodium permanganate (NaMnO_4) is highly soluble (40%; 400 g/L), produced and delivered as a solution, and only requires dilution (if desired) before injection. Therefore, precipitation of NaMnO_4 is not possible.

Disadvantages:

- A wide range of naturally occurring reactants other than the target contaminant(s) also react with MnO_4^- and impose a background oxidant demand. The background oxidant demand reduces oxidation efficiency and is generally greater than the demand imposed by the target COCs, which may increase the cost.
- The accumulation of manganese dioxide [$\text{MnO}_2(\text{solid})$] at the NAPL interface may interfere with mass transfer, and excessive accumulation in porous media may result in permeability reduction.
- The solubility of potassium permanganate (KMnO_4) is temperature-sensitive. Typical injection concentrations [2 to 3 grams per liter (g/L)] are well below the solubility (6.5 g/L @ 20 °C). However, differences in temperature between the KMnO_4 solution in the mixing tank and in the aquifer could result in precipitation of KMnO_4 in the aquifer where it is cooler. Accumulation of un-dissolved KMnO_4 particles in the well, in the sand and gravel pack around the well, and in the formation near the well, can cause loss in permeability.
- In subsurface systems involving significant reaction between MnO_4^- and high concentrations of organic chemicals, large quantities of carbon dioxide (CO_2) gas can be produced in the aquifer, resulting in CO_2 entrapment, and can cause permeability and hydraulic conductivity reductions in the aquifer.
- Hydraulic short circuiting and/or preferential pathways may result in the delivery of the oxidant into non-target zones.
- U.S. EPA has established a secondary maximum contaminant level for drinking water for manganese [0.05 milligrams per liter (mg/L)] based on color, staining, and taste.
- Permanganate will not react with benzene, one of the primary Site COCs.

Persulfate

Persulfate salts dissociate in aqueous solutions to form the persulfate anion $\text{S}_2\text{O}_8^{2-}$, which is a strong oxidant that can degrade many environmental contaminants. $\text{S}_2\text{O}_8^{2-}$ can also be catalyzed with various reactants to form the sulfate radical (SO_4^\cdot), a more powerful oxidant. Sodium persulfate ($\text{Na}_2\text{S}_2\text{O}_8$) is the most common and feasible form used in ISCO.

Advantages:

- Persulfate is more stable in the subsurface than H_2O_2 and O_3 , and the radical intermediate, SO_4^\cdot , is more stable than the hydroxide ion (OH^\cdot), suggesting fewer mass transfer and mass transport limitations.
- Persulfate will react with benzene, while permanganate does not, thus allowing this form of oxidant to be used in the remediation of fuel spills and benzene, toluene, ethylbenzene, and total xylenes (BTEX)-contaminated groundwater.
- Persulfate does not appear to react as readily with soil organic matter as permanganate.
- Low oxidant cost.
- High solubility.
- Persulfate can persist in the subsurface for weeks, suggesting that the natural oxidant demand for persulfate is low.
- Persulfate can be injected at high concentrations, can be transported in porous media, and will undergo density-driven and diffusive transport into low-permeability materials.

Disadvantages:

- Peer-reviewed literature is limited.
- Persulfate is less stable than permanganate and will not persist as long in subsurface systems.
- Catalysts are required in the persulfate reaction to produce the more powerful sulfate radical.
- There will likely be difficulties in achieving the optimal mix of reagents in the subsurface due to the lack of naturally occurring catalyst, and due to the difference in transport behavior of these reagents upon injection.
- Oxidant cost is higher than other oxidants, but may be offset by the lack of oxidant demand by non-target aquifer materials.

Hydrogen Peroxide/ Fentons

Fenton's reagent is a solution of hydrogen peroxide and an iron catalyst that is used to oxidize contaminants. Presented below is a summary of advantages and disadvantages (U.S. EPA, Huling and Pivetz):

Advantages:

- OH are a powerful non-specific oxidant that will react rapidly with many environmental contaminants.
- Reactions involving H_2O_2 are rapid, and it generally persists for <12 hours.
- Intermediate chemical species [O_2 , perhydroxyl radical (HO_2)] may reductively transform contaminants. Fenton oxidation could address complex mixtures of organic compounds.
- Enhanced natural attenuation may be attributed to O_2 gas and heat. Oxidized inorganics may also serve as terminal electron acceptors.
- Low cost of H_2O_2 .

Disadvantages:

- Excessive H_2O_2 decomposition via nonproductive reactions.
- Radical scavenging.
- Low reactive rate between some target contaminants and OH, O_2 , HO_2 .
- pH modification (acidification) is problematic in well buffered aquifers.
- Problematic delivery of H_2O_2 Fe(II), acid, and stabilizers due to reactive transport.
- Production of O_2 (gas) contributes to reductions in permeability. This may reduce the flow of groundwater and injected reagents through the targeted contaminant zones. It also results in sparging which contributes to volatilization and redistribution of contaminants.
- Pneumatic transport of volatiles, NAPL, and contaminated groundwater away from the injection point; heavy asphalt, excessive pressure.
- Incomplete oxidation and mobilization of metals.
- Excessive release of heat and elevated temperatures associated with high H_2O_2 concentrations may damage/melt PVC/plastic wells.
- Unproven use of stabilizer reagents.
- Health and safety issues regarding release of volatiles, steam, and strong oxidant solutions.

Calcium Peroxide/
Fentons (USAF)

This process uses calcium peroxide (CaO_2) powder as a source of H_2O_2 to promote modified Fenton chemistry, which slowly decomposes to release oxygen at a “controlled” rate.

Advantages:

- Imparts the alkalinity and peroxide needed to activate the persulfate.
- When mixed with water it provides a long-term slow release source of hydrogen peroxide and calcium hydroxide. The hydrogen peroxide that is slowly formed decomposes to oxygen and water, providing an extended oxygen source for subsequent bioremediation of petroleum hydrocarbons (taking up to several weeks to attenuate).
- The resultant calcium hydroxide (hydrated lime) that is produced serves several purposes:
 - It increases the total dissolved ion concentration, which makes the solution less likely to leach metals from the soil into the groundwater.
 - The calcium from the hydrated lime will precipitate the sulfate that is produced during the consumption of the persulfate.
- Works well with chlorinated VOCs, including chlorobenzene.
- Among the safest to handle of peroxide compounds. It represents no significant hazards with regards to skin contact, inhalation, or ingestion.

Disadvantages:

- The calcium sulfate (gypsum) precipitation helps to reduce sulfate groundwater concentrations, which may impact the secondary drinking water standard of 250 parts per million (ppm).
- It is vigorous and exothermic and can lead to VOC, oxygen (O_2) and peroxide gas evolution;
- If high concentrations of contaminants are encountered frothing and day lighting can occur;
- Significantly higher cost than other products.
- Calcium peroxide does not dissolve in water; therefore, this product can be difficult to disperse in the subsurface.
- The percentage of calcium peroxide is high for use as an activator.
- An oxidizer; therefore, contact with combustible materials (paper, cotton, organics, wood, leather, reducing agents, and other oxidizers) should be avoided.

Ozone

O₃ is a gas and a strong oxidant that is sparingly soluble in water and upon reaction does not leave a residual other than O₂. The solubility of O₃ is relatively low and is functionally dependent on temperature and the partial pressure of O₃ in the gas phase. Decomposition is much more rapid in the aqueous phase than in the gas phase due to the strong catalyzing reaction by the OH⁻.

Advantages:

- O₃ reacts with many, but not all important environmental contaminants.
- In-situ ozonation in the unsaturated zone is favorable relative to the saturated zone because: higher concentrations of O₃ can be injected, O₃ is more stable in gas than in water, diffusive transport is greater, and higher velocities (mass delivery rates) can be achieved.
- Co-injection and reaction of H₂O₂ and O₃ can yield OH, a strong, nonspecific oxidant.

Disadvantages:

- The instability of O₃ requires that it be generated on site and to be injected under pressure. Under this condition, hydraulic seals and other materials used in the remedial equipment must be compatible with ozone or they will rapidly deteriorate.
- O₃ has a short retention time in the subsurface because it reacts rapidly with a wide range of naturally occurring non-target chemical species (reduced minerals, organic matter, etc.), including OH⁻.
- O₃ has a relatively low solubility in water and is highly vulnerable to hydraulic short circuiting as a gas in the unsaturated zone.
- O₃ injected into the saturated zone is poorly/non-uniformly distributed and is transported very short distances.
- Specialized oxidant-resistant materials are likely to be required. Enhanced volatilization of contaminants may result from sparging the groundwater with O₃ (gas) and O₂ (gas).
- Since volatile organics and O₃ both represent a threat to human health, collection of volatile emissions (off-gases) using a vacuum extraction system may be required to minimize potential exposure pathways.
- O₃ does not react at an appreciable rate with some important environmental contaminants.

RegenOx™:

RegenOx™ is a proprietary ISCO process using a solid oxidant complex (sodium percarbonate/catalytic formulation) and an activator complex (a composition of ferrous salt embedded in a micro-scale catalyst gel).

Advantages:

- RegenOx™ with its catalytic system has very high activity, capable of treating a very broad range of soil and groundwater contaminants including both petroleum hydrocarbons and chlorinated solvents.
- RegenOx™ has significant longevity in the subsurface allowing for both the initial contaminant degradation and the continued treatment of contaminants desorbing from the matrix.
- RegenOx™ is less immediately reactive, allowing for wider distribution.
- Unlike permanganate and persulfate, RegenOx™ does not add compounds that will potentially have an adverse impact on water quality and bioremediation. Secondary drinking water standards exist for sulfate and manganese, and the use of these chemicals to treat groundwater jeopardizes the quality of the water after treatment.
- When developing RegenOx™, a main objective was to employ an oxidant within the formulation that would not negatively interfere with bioremediation processes that would occur after the oxidation was complete. The RegenOx™ system leaves behind very little residue, limited primarily to the innocuous carbonate and bicarbonate ions. These residuals do not have a negative effect or interfere with efficient natural attenuation or enhanced bioremediation.
- With regard to shifting the geochemistry of the aquifer and the potential to increase the concentration of dissolved heavy metals, RegenOx™ generates basic conditions. Metals mobilization is less likely under basic conditions than acidic conditions. Furthermore, mobilized metals are typically stabilized by the geochemical conditions of the aquifer.

Disadvantages:

- Peer-reviewed literature is limited.
- More complex reaction chemistry than other oxidants, using both a solid oxidant complex and an activator complex.
- There will likely be difficulties in achieving the optimal mix of reagents in the subsurface.
- Oxidant cost is higher than other oxidants.

3.4 TESTING PROCEDURES

Capture and quantification of contaminant losses from the reactor is necessary to maintain a mass balance and to assess treatment performance. These losses include volatiles, displacement of aquifer material, and aqueous solutions. Recommended monitoring parameters that are a direct indicator of oxidative treatment include the target COCs, reaction byproducts, metals, and the oxidant.

3.4.1 Oxidants

Based on the information referenced and presented in Section 3.3, the following compounds will be evaluated during the Bench-Scale Treatability Study:

- Iron catalyzed sodium persulfate
- Calcium peroxide catalyzed sodium persulfate
- Iron catalyzed calcium peroxide
- RegenOx™

Testing

Once the samples are received at the bench-scale testing contractor, the following activities will be performed:

- Homogenize the soil by mixing gently, avoid vigorous mixing that may grind the particles, release VOCs, or alter the soil properties.
- Measure the pH of the soil mixture.
- From each of the test zones (as previously defined), 12 1-liter jars per sample interval will be prepared with a combination of soil and groundwater from the Site. Based on existing information, each jar is anticipated to be prepared with approximately 500 grams of soil and groundwater to fill the 1-liter jar. The 500 grams of soil to be placed into each of the 12 jars will be selected to be representative of the entire sampling interval, such that each 500-gram sample of soil will be similar to the other 500-gram samples (i.e., based on the percentage of sand, silt, clay, and gravel), based on visual observations of grain size and other soil properties observed in the laboratory. Preparation of the jars in this manner will allow the soil within each jar to be comparable to other jars and representative of field conditions.
- For each set of samples one test jar will be prepared and used as a control.

- The jars will be maintained in a dark environment at a temperature equivalent to the media's natural environment and allowed to equilibrate for 2 to 3 days.
 - For each test, 50 milliliters (ml) of groundwater will be extracted from each jar prepared with soil from the same interval and replaced with 50 ml of 10% oxidant solution in each jar. The 10% oxidant solution was proposed based on experience with the proposed oxidants. Solutions with greater concentrations of oxidant tend to result in high reaction rates that cannot be safely handled in the laboratory, and solutions with lower concentrations of oxidant result in lower reaction rates that can be difficult to measure in the laboratory, or that are difficult to distinguish from other mechanisms, such as desorption.
 - For the control samples, 50 ml of groundwater will be extracted from the jars prepared with soil from the same interval and replaced with 50 ml of groundwater. Historically, some volatilization or some desorption from the soil will cause the post-treatment sample results to be somewhat lower or higher than the pre-treatment sample. This change is assumed to be a function of the testing process and a correction is applied to all of the treatment samples.
 - The extracted water from each jar will be managed as follows:
 - Extracted water from each of the containers will be combined and placed into analyte specific laboratory provided sample containers.
 - Containers will be forwarded to Heritage Environmental Services, LLC laboratory in Indianapolis, Indiana for analysis of:
 - Main Plant Source Area - VOCs by U.S. EPA Test Method 8260, SVOCs by U.S. EPA Test Method 8270 (Low Level), and metals by U.S. EPA Test Method 6010/7000/7000.
 - 1855 Source Area – VOCs by U.S. EPA Test Method 8260, SVOCs by U.S. EPA Test Method 8270 (Low Level), and metals by U.S. EPA Test Method 6010/7000/7000.
 - 1831 Floodplain Source Area - VOCs by U.S. EPA Test Method 8260, SVOCs by U.S. EPA Test Method 8270 (Low Level), and metals by U.S. EPA Test Method 6010/7000/7000.
- Note:** Tentatively Identified Compound (TIC) analysis will be performed on VOCs and SVOCS, if the sample volume is adequate to perform this analysis. This analysis will be performed to identify potential breakdown products.
- Each test jar will be agitated for approximately 60 seconds and maintained under the following conditions:
 - Maintained at a temperature consistent with the media's natural environment;
 - Maintained in a dark setting; and,
 - Maintained in a sealed container.

This material will then be allowed to remain in these conditions for a period of approximately 30 days to allow for the chemical oxidation process to reach its conclusion. At that point, the water will be extracted from the test vessels and submitted for analysis, as defined above.

- After completion of sample collection, the testing process will be continued to obtain additional bench-scale treatability testing data. However, the decision to submit additional samples for laboratory analysis will be based on the subsequent sample results. The goal is to allow the bench-scale treatability testing to proceed until completion of the chemical reaction.
- Concentrations associated with all three phases (solid, liquid, and vapor) will be measured both before the addition of the oxidant and after the test is completed. In addition, testing for COD, BOD, DO, CO₂, nitrates and sulfates will be performed at the conclusion of the bench-scale treatability testing to estimate the on-going biodegradation potential.
- A mass balance analysis will be conducted based on the measured concentrations prior to initiation of oxidant introduction and at the conclusion of oxidant testing.

In addition to the above bench-scale testing, a portion of the collected soil samples will be analyzed for total oxidant demand (TOD), which will be used to evaluate oxidant loading to be used during the Pilot-Scale Treatability Study.

3.5 BENCH-SCALE TREATABILITY STUDY RESULTS

After the Bench-Scale Treatability Study is completed, the results will be summarized in a technical memorandum and submitted to U.S. EPA. The results of the Bench-Scale Treatability Study will be utilized in designing the following specific aspects of the Pilot-Scale Treatability Study for each source area:

- Selection of one specific chemical oxidant for the pilot-scale study, using a model that incorporates the following criteria to evaluate the bench-scale results:
 - Reduction of primary COC concentrations;
 - Potential for negative effects (e.g., metals mobilization, daughter product generation);
 - Impact of oxidant on future treatment, such as bioenhancement and MNA; and,
 - Oxidant costs.
- Identification of the chemical oxidant injection dosage (concentration, rate, and volume).
- The potential for metals mobilization.
- The bioenhancement chemical and its proposed pilot-scale dosage, which will be refined based on the bench-scale testing results. ~~The potential impact of the selected oxidant on future treatment, such as bioenhancement and MNA, will be analyzed~~ Design factors to be considered in selection and dosing of the bioenhancement chemical include:-
 - Effectiveness in reducing primary COC concentrations based on a literature search and relevant experience;

- Anticipated COC concentrations remaining after the ISCO phase of Pilot-Scale Test, based on Bench-Scale results;
- Experience with various ISCO/bioenhancement chemical combinations (compatibility);
- Impact of selected oxidant on bioenhancement and MNA; and,
- Bioenhancement chemical costs.

4.0 PILOT-SCALE TREATABILITY STUDY

Upon completing the Bench-Scale Treatability Study and prior to full-scale implementation, a Pilot-Scale Treatability Study will be performed. The Pilot-Scale Treatability Study will include both the chemical oxidant selected following the Bench-Scale Treatability Study and a bioenhancement chemical. Any recommended modifications to the proposed Pilot-Scale Treatability Study presented below, based on the results of the Bench-Scale Treatability Study, will be included within the technical memorandum for the Bench-Scale Treatability Study. Also, a brief letter report will be submitted following the ISCO phase of the Pilot-Scale Test but before the bioenhancement phase of the Pilot-Scale Test in order to incorporate information learned during the ISCO phase into the bioenhancement phase.

The objectives of the Pilot-Scale Treatability Study are to determine COC destruction efficiency, the timeframe for treatment, density of application and resultant treatment zone size, and the viability of the ISCO/enhanced bioremediation approach to achieve the treatment goal of providing additional assurance that EPC will not be exceeded at POC wells in the future.

COC destruction efficiency will be evaluated as a measure of how well the treatment area is able to effectively remove primary COC concentrations from the aqueous phase. In addition, concentration vs. time plots (combined with the concentration vs. distance plots) will help develop treatment timeframes.

4.1 PILOT-SCALE PROGRAM

The Pilot-Scale Treatability Study will focus on a portion of the source area, which is located hydraulically up-gradient of the center of the source area, thereby minimizing the potential that the treated area will become impaired after completion of the Pilot-Scale Treatability Study and prior to full-scale implementation. Presented below are the areas proposed for each of the three source areas.

4.1.1 Main Plant Source Area

The Pilot-Scale Treatability Study for this source area will consist of the injection of the selected chemical oxidant into three injection wells shown in green on Figure 11 (one located east of

1818, one located southeast of 1908, and one located between 1908 and 1814) and operation of one groundwater extraction well (1880) shown in blue on Figure 11.

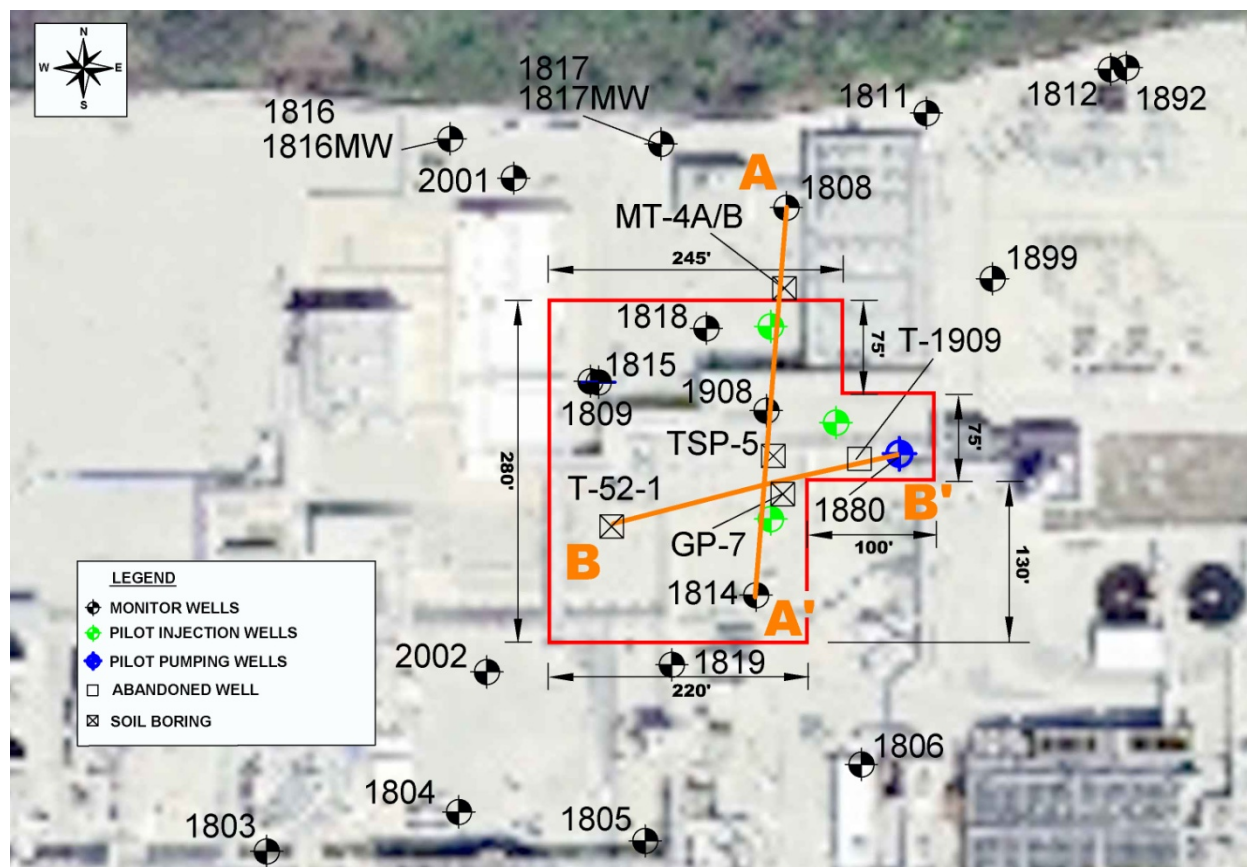


Figure 11 – Main Plant Source Area Pilot-Scale Locations

Bioenhancement chemical injection will utilize the same three pilot injection wells, and will be scheduled approximately ~~four~~twelve weeks following the completion of chemical oxidant injection. Groundwater extraction well 1880 will be operated during and following the bioenhancement chemical injection for the same length of time as it operates following the chemical oxidant injection pilot program (i.e., anticipating similar travel times for distribution).

Performance monitoring during the Pilot-Scale Treatability Study will include monitor wells 1818, 1908, 1814, 1808, and 1880 (after operation of this well ceases). Data gathered during

performance of this monitoring will be used to confirm the quantity of bioenhancement chemical to be injected, which will be provided in the brief letter report.

Table 1 provides information regarding distance from the pilot injection wells and estimated travel times of oxidant solution to the five monitor wells. These estimations of groundwater travel times use simplified groundwater flow assumptions (see Attachment 2). A volumetric calculation was made to calculate the chemical radius of influence during injection, and then non-pumping flow was estimated using the Darcy flow equation:

$$v = K \cdot i / n, \text{ where}$$

v = seepage velocity

K = hydraulic conductivity

I = hydraulic gradient

n = porosity

The effect of pumping from well 1880 at a rate of one gallon per minute was estimated using Neuman type curve analysis.

Since the treatment area is located across the Unit I groundwater divide, and pumping well 1880 will be turned on five days prior to the start of the injection events, it is anticipated that injected fluid will reach each of the five monitor wells.

Table 1 – Travel Times to Monitor Wells, Main Plant Source Area

Monitor Well	Distance From Nearest Injection Point To Monitor Well, Feet	Travel Time To Monitor Well, Days
1880 (pumping)	50	1.7
1908	50	19
1818	50	19
1814	65	25
1808	100	39

Assumptions:

- Hydraulic Conductivity = 0.06 ft/min (Harza, 1989. *Phase E Site Assessment Report*)
- Porosity = 0.30 (Fetter, 1988. *Applied Hydrogeology*)
- Specific Yield of Aquifer = 0.25 (Fetter, 1988. *Applied Hydrogeology*)
- Saturated Thickness = 18 feet (CMS Report conceptual design)
- Volume Injected = 2,800 gallons (including 50 gallon flush of clean water)
- Injection Rate = 5 gpm (CMS Report conceptual design)
- Chemical Radius of Influence at end of injection period = 4.7 feet (calculated)
- Static Hydraulic Gradient = 0.009 ft/ft (Based on Q2 2010 potentiometric map, CMS Report)
- 1880 Pumping Rate = 1 gpm
- 1880 Radius of Influence (at 5 days) = 216 feet (calculated)
- Used Neuman type curve analysis to account for pumping conditions.

4.1.2 1855 Source Area

The Pilot-Scale Treatability Study for this source area will consist of the injection of the selected chemical oxidant into three pilot injection wells installed during the sampling for the Bench-Scale Treatability Study and located along the central portion of the eastern most line of injection wells, east of 2011, shown in green on Figure 12.

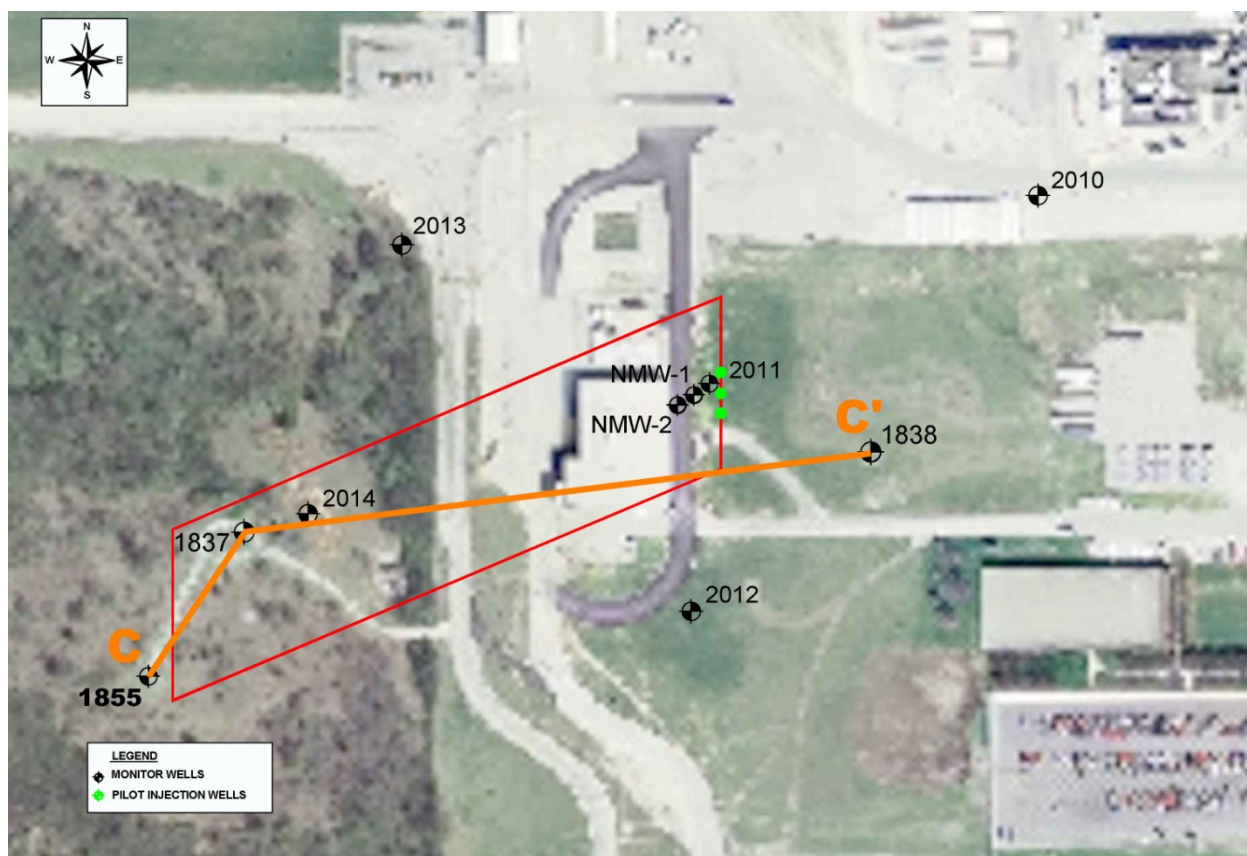


Figure 12 – 1855 Source Area Pilot-Scale Locations

Bioenhancement chemical injection will utilize the same three pilot injection wells, and will be scheduled approximately ~~four~~twelve weeks following the completion of chemical oxidant injection.

Performance monitoring will include monitor well 2011, and two new monitor wells, located approximately 30 feet (NMW-1) and 60 feet (NMW-2) down-gradient of the pilot injection wells, as shown on Figure 12. Data gathered during performance of this monitoring will be used to confirm the quantity of bioenhancement chemical to be injected, which will be provided in the brief letter report.

Table 2 provides information regarding distance from the pilot injection wells and estimated travel times of oxidant solution to the three monitor wells. These estimations of groundwater travel time use simplified groundwater flow assumptions (see Attachment 2). A volumetric

calculation was made to calculate the chemical radius of influence during injection, and then non-pumping flow was estimated using the Darcy flow equation:

$$v = K \cdot i / n, \text{ where}$$

v = seepage velocity

K = hydraulic conductivity

I = hydraulic gradient

n = porosity

Since the monitor wells are located immediately down-gradient of the injection wells, it is anticipated that injected fluid will reach each of the three monitor wells.

Table 2 – Travel Times to Monitor Wells, 1855 Source Area

Monitor Well	Distance From Nearest Injection Point To Monitor Well, Feet	Travel Time To Monitor Well, Days
2011	5	0.04
New Monitor Well – 1	30	25
New Monitor Well – 2	60	56

Assumptions:

- Hydraulic Conductivity = 0.06 ft/min (Harza, 1989. *Phase E Site Assessment Report*)
- Porosity = 0.30 (Fetter, 1988. *Applied Hydrogeology*)
- Saturated Thickness = 1.5 feet (CMS Report conceptual design)
- Volume Injected = 260 gallons (including 10 gallon flush of clean water)
- Injection Rate = 5 gpm (CMS Report conceptual design)
- Chemical Radius of Influence at end of injection period = 5.0 feet (calculated)
- Static Hydraulic Gradient = 0.003 ft/ft (Based on Q2 2010 potentiometric map, CMS Report)

4.1.3 1831 Floodplain Source Area

Based on the anticipated footprint of the treatment area (approximately 50 feet by 100 feet), the proposed Pilot-Scale Treatability Study will encompass the entire area of the proposed full-scale treatment area. The Pilot-Scale Treatability Study for this source area will consist of the injection of the selected chemical oxidant into 14 pilot injection wells, shown in blue on Figure 13.

Bioenhancement chemical injection will utilize the five southern-most (up-gradient) pilot injection wells, and will be scheduled approximately ~~four~~twelve weeks following the completion of chemical oxidant injection.

Performance monitoring will include monitor wells 1831, 1833, 1834, 1832, and 1876. Data gathered during performance of this monitoring will be used to confirm the quantity of bioenhancement chemical to be injected, which will be provided in the brief letter report.

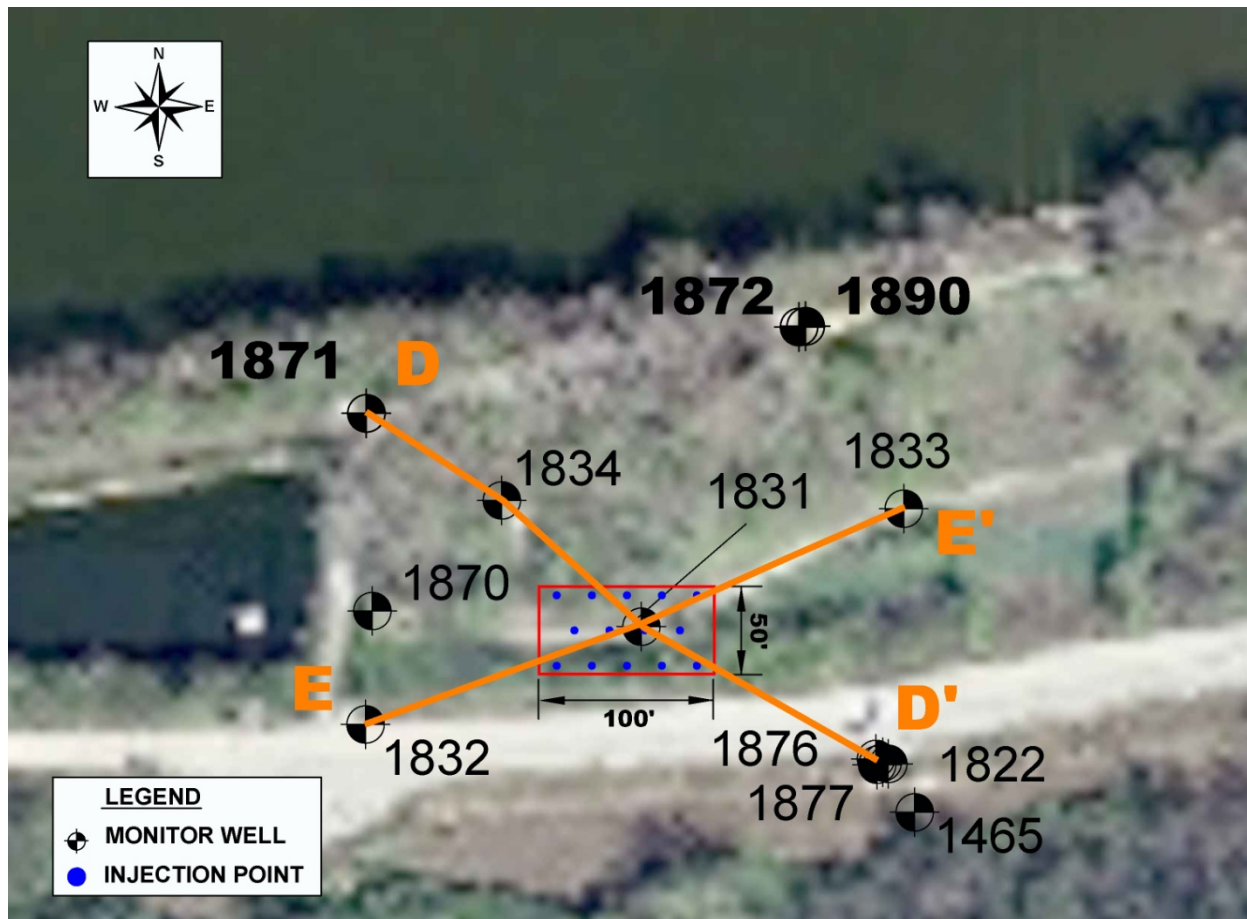


Figure 13 – Floodplain – 1831 Source Area Pilot-Scale Locations

Table 3 provides information regarding distance from the pilot injection wells and estimated travel times of oxidant solution to the five monitor wells. These estimations of groundwater travel times use simplified water flow assumptions (see Attachment 2). A volumetric calculation

was made to calculate the chemical radius of influence during injection, and then non-pumping flow was estimated using the Darcy flow equation:

$$v = K \cdot i / n, \text{ where}$$

v = seepage velocity

K = hydraulic conductivity

I = hydraulic gradient

n = porosity

Since monitor wells 1832 and 1876 are located generally hydraulically up-gradient of the injection wells, it is likely that injected fluid will not reach these two monitor wells. However, since the groundwater flow direction and gradient in the floodplain area is variable and dependent upon flood stage of the Wabash River, these two wells will be monitored to see if any response is observed.

Table 3 – Travel Times to Monitor Wells, 1831 Floodplain Source Area

Monitor Well	Distance From Nearest Injection Point To Monitor Well, Feet	Travel Time To Monitor Well, Days
1831	10	5
1834	50	29
1833	100	58
1832	100	-----
1876	120	-----

Assumptions:

- Hydraulic Conductivity = 0.008 ft/min (Harza, 1989. *Phase E Site Assessment Report*)
- Porosity = 0.35 (Fetter, 1988. *Applied Hydrogeology*)
- Saturated Thickness = 20 feet (CMS Report conceptual design)
- Volume Injected = 300 gallons (including 50 gallon flush of clean water)
- Injection Rate = 5 gpm (CMS Report conceptual design)
- Chemical Radius of Influence at end of injection period = 1.4 feet (calculated)
- Static Hydraulic Gradient = 0.05 ft/ft (Based on Q2 2010 potentiometric map, CMS Report)

4.2 PERMITTING

Wells for the injection of chemical oxidants may be considered Class V injection wells as per the federal Underground Injection Control (UIC) Program, which falls under the federal Safe Drinking Water Act (SDWA). Prior to performing the Pilot-Scale Treatability Study, Lilly will contact both IDEM and U.S. EPA and confirm whether injection of chemical oxidants would require a permit. If required, a permit application form will be completed and submitted to the IDEM/U.S. EPA UIC Program.

4.3 INJECTION WELL/POINT INSTALLATION

4.3.1 Main Plant Source Area Injection Well Installation

To allow for selection of the oxidant injection zone, the depth to groundwater, saturated soil lithology, well screened intervals, and primary COC concentrations for monitor wells located within the footprint of the proposed treatment area must be understood. Table 4 presents a summary of this information, and Figures 14 and 15 present cross-sections of the main plant treatment area. The orientation of the cross-sections are presented on Figure 11. Soil boring logs for existing monitor wells are included in Attachment 1.

Table 4 - Main Plant Source Area Data Summary

Well ID	Depth to Water (feet bgs)	Depth Interval (feet bgs)	Lithology	Screen Interval (feet bgs)	Depth Discrete Sampling Interval	Benzene (ug/L)	CB (ug/L)	pCBT (ug/L)	THF (ug/L)	n,n-DEA (ug/L)
1809	61	50 - 70	Sand, F. - C, with Gravel							
		70 - 75	Clay	74 - 94	74 - 94	4,367.60	356.23	0.08	17,491.23	19,905.24
		75+	???							
1814	61	54 - 67	Sand, Fine with Gravel	55 - 67	61 - 90	1,506.85	116.60	0.29	176.81	14,015.58
		67 - 87	Clay	80 - 90						
		87 - 88	sand and Gravel							
		88 - 90	Sandy Clay							
		90	Clay							
1815	64	43 - 68.5	Sand, Gravelly	66 - 96	66 - 96	17,019.16	372.21	0.06	242,640.43	12,636.53
					66 - 69	5,338.72	488.30	0.07	28,208.93	11,545.70
		68.5 - 70.5	Silty Sand and Clay							
		70.5 - 78	Silty Clay and Silt							
		78 - 96	Silty Sand and Sand		78 - 81	8,867.50	456.78	0.05	48,921.13	11,796.17
					93 - 96	37,358.93	88.72	<2.0	928,397.05	5,802.16
1818	63	45 - 66	Sand, Fine to Coarse	44.5 - 64.5	63 - 84.5	225.04	445.20	0.38	3.47	6,888.54
		66 - 78	Sandy Clay	74.5 - 84.5	75 - 78	69.52	539.26	0.43	<0.73	5,554.78
		78 - 98	Clay							
1819	61	61 - 82	Gravelly Sand	54 - 89	61 - 89	6.05	45.41	<0.02	<0.73	9,696.16
					61 - 64	16.01	827.00	0.34	<0.73	13,714.90
					70 - 73	7.70	333.05	0.14	<0.73	7,076.31
					79 - 82	4.61	98.74	0.06	<0.73	2,923.62
		82 - 94	Silty Sand							
1880	64	61.5 - 66	Sandy Clay Loam	63 - 68	63 - 68	1,301.10	48.21	0.70	891.71	70,677.24
		66 - 68	Sand with Gravel							
		68	Clay							
1908	62	No Log		67 - 72	67 - 72	0.22	7.79	1.18	ND	ND
Interval Samples - Collected June - July 2009										
Discrete Samples - Collected Q3 2009										
Screened intervals only present screen that extends across a saturated interval. Screened intervals in the vadose zone are not presented.										

Based on the preliminary ISCO approach and the area-specific information summarized above, a total of three injection wells will be installed for the Pilot-Scale Treatability Study. One of these injection wells will have already been installed during sampling for the Bench-Scale Treatability Study.

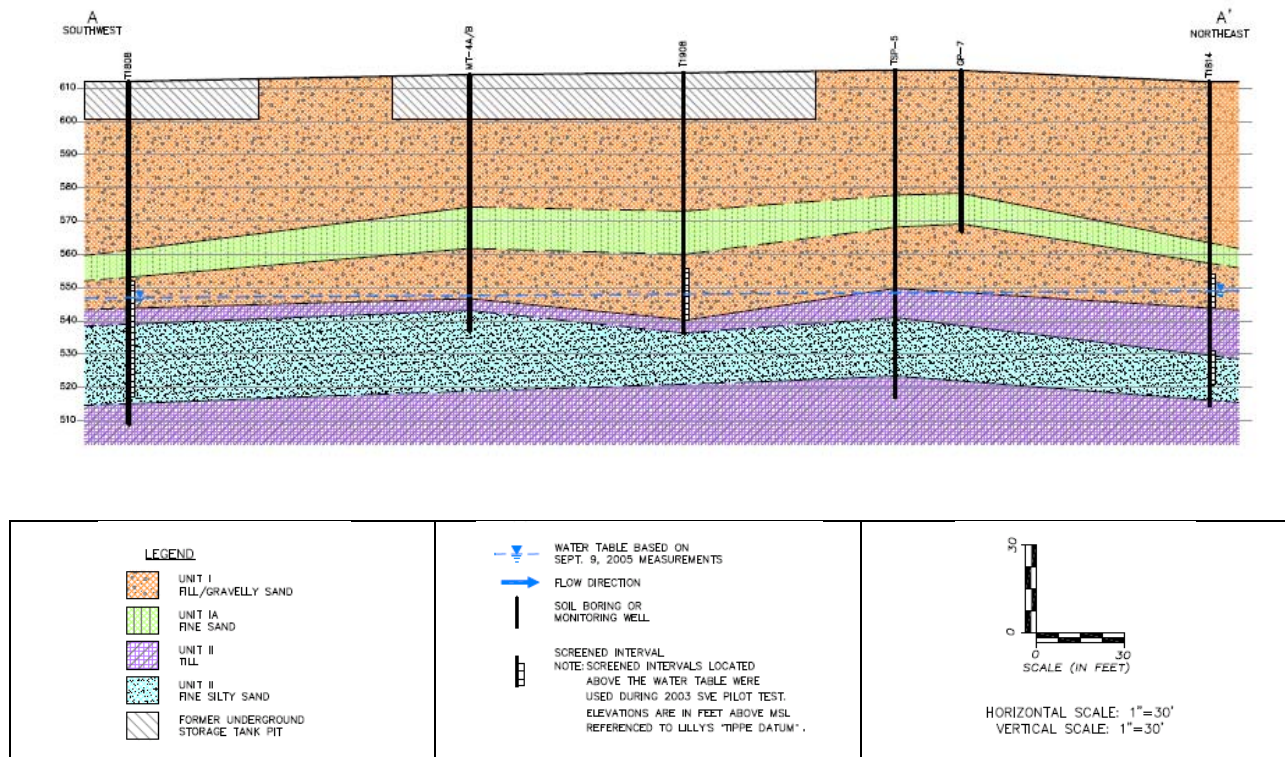


Figure 14 – Main Plant Source Area Cross Section A-A'

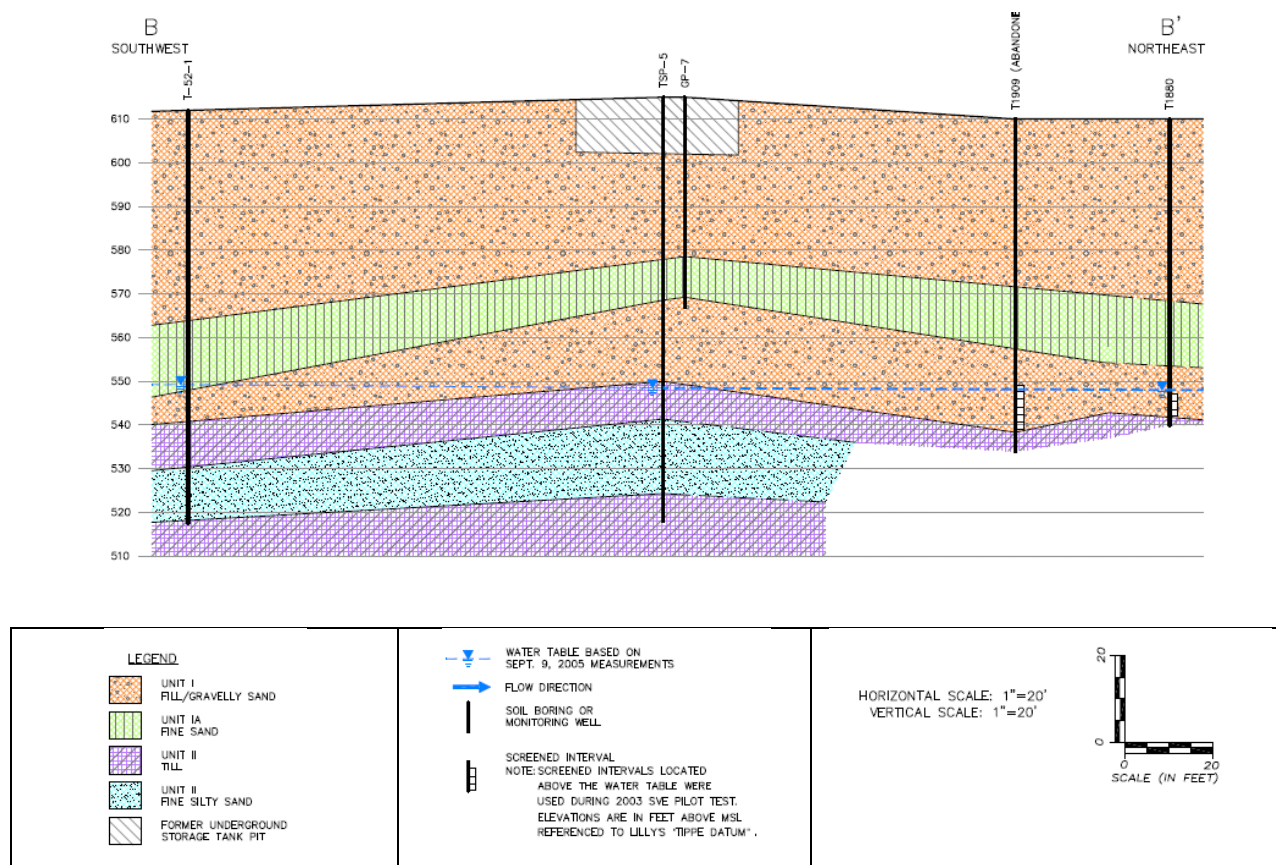


Figure 15 – Main Plant Source Area Cross Section B-B'

4.3.1.1 Utility Clearance

Prior to initiation of subsurface field activities, a site reconnaissance will be completed to stake and clear the proposed investigation locations. After location staking, Evonik will be contacted to identify subsurface utilities located in investigation area.

4.3.1.2 Soil Boring/Injection Well Installation

Soil borings required for injection well installation will be advanced with a truck-mounted, hollow-stem auger drilling rig or sonic rig. Soil samples will be collected continuously from five feet above the water table to the total depth of the soil boring, estimated to range between 55 and 90 feet bgs.

Once the soil samples are aboveground, a field representative will describe the soils according to the USCS, equivalent to ASTM D2488. In addition, a portion of each soil sample will be placed into individual Ziploc bags and the headspace gas will be monitored with a PID. This field screening technique, along with visual and olfactory observations of the soil, will be utilized to select two soil samples from each location for chemical analyses from the saturated interval. Documented observations of the soil samples will consist of sample depth, lithology, color, structure, staining, degree of sample saturation, and the presence or absence of hydrocarbon odors. An Indiana LPG will sign off on the geologic boring logs.

After reaching the soil boring target depth, the inner rod of the augers will be removed and well completion procedures will commence. The injection wells will be constructed by installing screen across the entire Unit I saturated interval, based on historic data and field observations. Wells will be completed with 0.040-inch slotted, 2-inch diameter, Schedule 40, flush threaded PVC screen; and 2-inch diameter, Schedule 40, flush threaded PVC casing to extend the well to ground surface.

Upon completion of well casing and screen installation, filter pack will be placed within the annular space between the injection well casing and screen and the hollow-stem augers to a height of approximately two feet above the screened interval. Concurrent with filter pack installation, the augers will be removed. This completion procedure will ensure that filter pack will be appropriately placed in the well completion. Thereafter, approximately two feet of granular bentonite will be installed above the filter pack and a cement/bentonite grout will be installed from the bentonite seal to the base of the locking-cap assembly. The injection well will then be completed within flush-mounted well completions, slightly elevated from the surrounding paved surfaces.

The following information will be entered into the well construction log:

- Project name;
- Project location;
- Drilling subcontractor;
- Field representative;
- Well identification;
- Date installed;
- Completion materials and corresponding depths (bgs);
- Top-of-casing and ground level elevations; and,
- Surface completion.

After the cement and concrete are allowed to cure for approximately 24 hours, well development activities will commence. Development activities will continue until developed water is relatively free of suspended sediment and field pH, specific conductance, and temperature measurements are equilibrated. Upon well completion, an Indiana-licensed public land surveyor will be retained to establish top-of-casing elevation for the newly installed wells.

Following completion of the Pilot-Scale Treatability Study, pilot injection wells will be considered for plugging in accordance with 312 IAC 13-10-2. A final recommendation as to whether the injection wells will be plugged will be made in the Final Treatability Study Report.

4.3.1.3 Analytical Laboratory Testing

Soil samples will be placed into laboratory provided sample containers and labeled with the following information: location, ID number, sample container, depth (soil), date, time, and sampling personnel. This information will also be entered on a chain-of-custody form. Soil samples will be placed into a cooler and chilled to a temperature of approximately 4°C for shipment to a Heritage Environmental Services, LLC laboratory in Indianapolis, Indiana for analysis of VOCs by U.S. EPA Test Method 8260, SVOCs by U.S. EPA Test Method 8270, and metals by U.S. EPA Test Method 6010/7000.

4.3.1.4 Decontamination and Field Derived Waste Disposal

Drilling and sampling equipment will be decontaminated prior to the initiation of soil boring/well installation activities. Decontamination fluids and personal protective equipment generated during the field investigation will be stored on-site in drums and properly disposed at the completion of field activities and receipt of analytical results.

4.3.2 1855 Source Area Injection Well Installation

To allow for selection of the oxidant injection zone, the depth to groundwater, saturated soil lithology, well screened intervals, and primary COC concentrations for monitor wells located within the footprint of the proposed treatment area must be understood. Table 5 presents a summary of this information, and Figure 16 presents a cross-section of the 1855 treatment area. The orientation of the cross-section is presented on Figure 12. Soil boring logs for existing monitor wells are included in Attachment 1.

Table 5 – 1855 Source Area Data Summary

Well ID	Depth to Water (feet bgs)	Depth Interval (feet bgs)	Lithology	Screen Interval (feet bgs)	Depth Discrete Sampling Interval	Benzene (ug/L)	CB (ug/L)	pCBT (ug/L)	THF (ug/L)	n,n-DEA (ug/L)
1837	65	4 - 66	Sand and Gravel	63-68	65-68	ND	ND	410.25	ND	ND
		66 - 70	Clayey Till							
1838	65	63 - 72.5	Sand, Med - C.	78-83	78-83	ND	0.78	0.21	ND	1.87
		72.5 - 83	Sand, C. - Sm. Gravel							
		83 - 90	Sand, Fine							
1855	69.5	63.5 - 69	Sand, Med -C. w/Gravel	67.5 - 72.5	69.5 - 72.5	ND	ND	114.44	ND	ND
		69 - 75.5	Clay							
2010	NM	No Log		63-68	63-68	NM	NM	30	NM	NM
2011	NM	No Log		68-73	68-73	NM	NM	500	NM	NM
2012	NM	No Log		67-72	67-72	NM	NM	52	NM	NM
2013	NM	No Log		65-70	65-70	NM	NM	8.9	NM	NM
2014	NM	No Log		67-72	67-72	NM	NM	360	NM	NM

Interval Samples - Collected Q4 2009

Screened intervals only present screen that extends across a saturated interval. Screened intervals in the vadose zone are not presented.

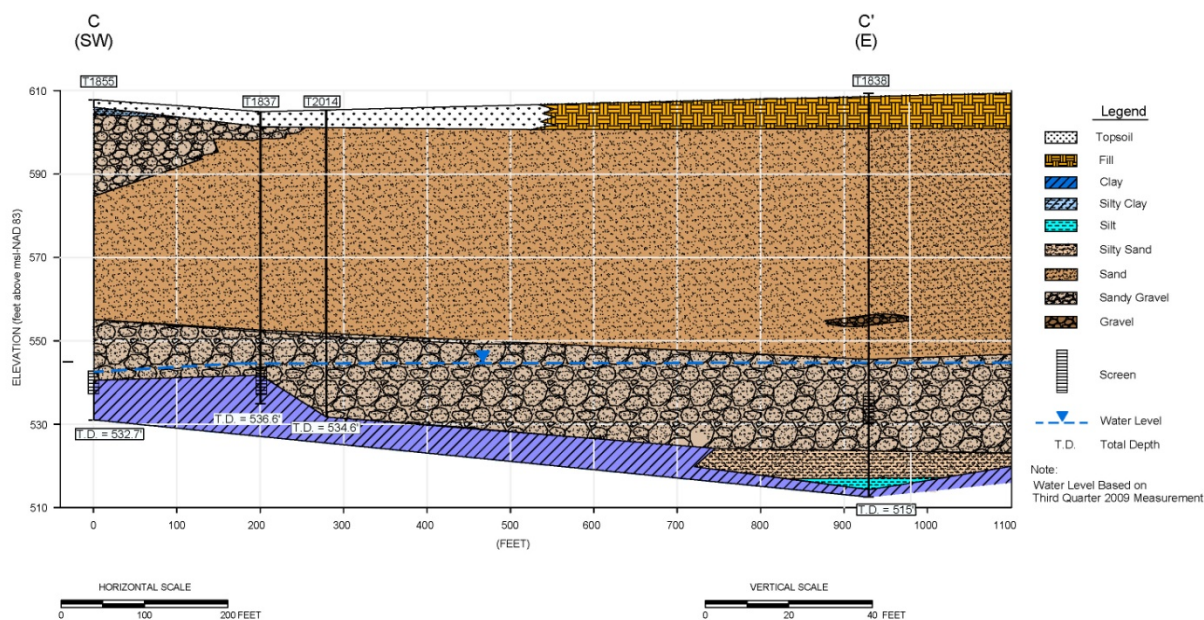


Figure 16 – 1855 Source Area Cross Section C-C'

Based on the preliminary ISCO approach and the area-specific information summarized above, a total of three injection wells and two new monitor wells will be utilized for the Pilot-Scale Treatability Study. All five of these wells would have been installed during sampling for the Bench-Scale Treatability Study.

Following completion of the Pilot-Scale Treatability Study, pilot injection wells will be considered for plugging in accordance with 312 IAC 13-10-2. A final recommendation as to whether the injection wells will be plugged will be made in the Final Treatability Study Report.

4.3.3 1831 Floodplain Source Area

To allow for selection of the oxidant injection zone, the depth to groundwater, saturated soil lithology, well screened intervals, and primary COC concentrations for monitor wells located within the footprint of the proposed treatment area must be understood. Table 6 presents a summary of this information, and Figures 17 and 18 present cross-sections of the floodplain treatment area. The orientation of the cross-sections is presented on Figure 13. Soil boring logs for existing monitor wells are included in Attachment 1.

Table 6 – 1831 Floodplain Source Area Data Summary

	Depth to Water	Depth Interval		Screen Interval	Depth Discrete Sampling Interval	Benzene	CB	pCBT	THF	n,n-DEA
Well ID	(feet bgs)	(feet bgs)	Lithology	(feet bgs)		(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
1831	10.75	9 - 11	Clayey Sand, F-M	23-28	23-28	697.64	201.66	0.16	2,422.80	ND
		11 - 24	Silty Clay							
		24 - 27	Silty Sand, F-C							
		27 - 30	Silty Sand, F							
1832	12.22	10.5 - 15	Silty Sand, F-C	13-18	13-18	5.54	184.38	4.16	ND	5.91
		15 - 22	Silty Clay							
1833	5.44	0 - 9	Silty Clay	13-18	13-18	ND	ND	0.10	ND	ND
		9 - 11	Clayey Silt							
		11 - 18.5	Sand and Gravel, M-C							
1834	9.98	4 - 21.5	Silty Clay	22.5-27.5	22.5-27.5	0.31	14.59	ND	ND	0.34
		21.5 - 30	Sand, M-C							
1876	12.9	12.3 - 18	Silty Sand, F-C	13-18	13-18	2.81	4.73	ND	ND	43.23
		18 - 21	Sand							
Interval Samples - Collected Q3 2009										
Screened intervals only present screen that extends across a saturated interval. Screened intervals in the vadose zone are not presented.										

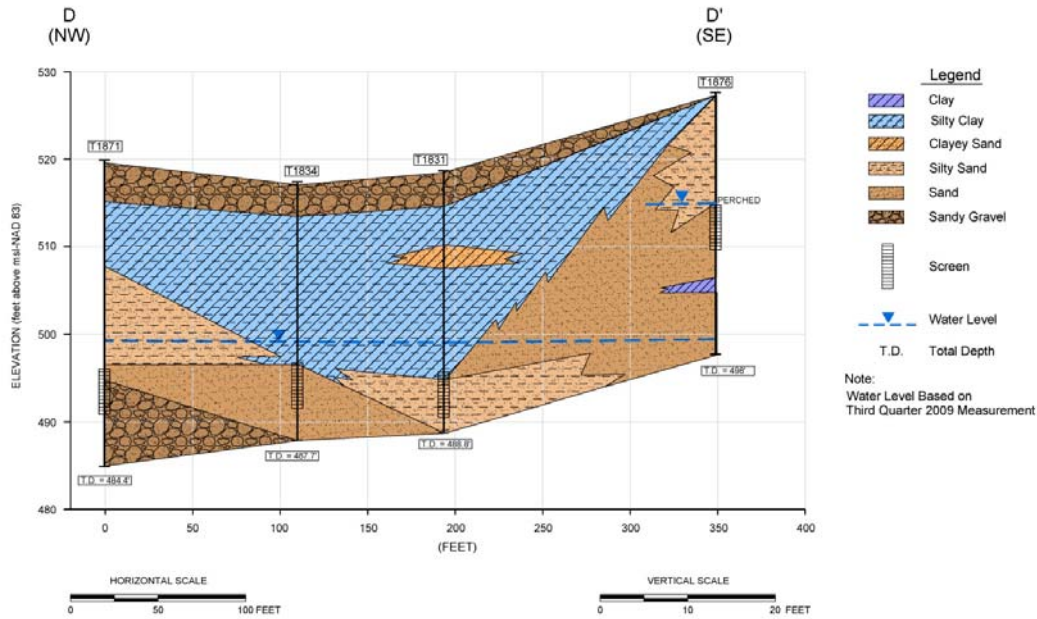


Figure 17 – 1831 Floodplain Source Area Cross Section D-D'

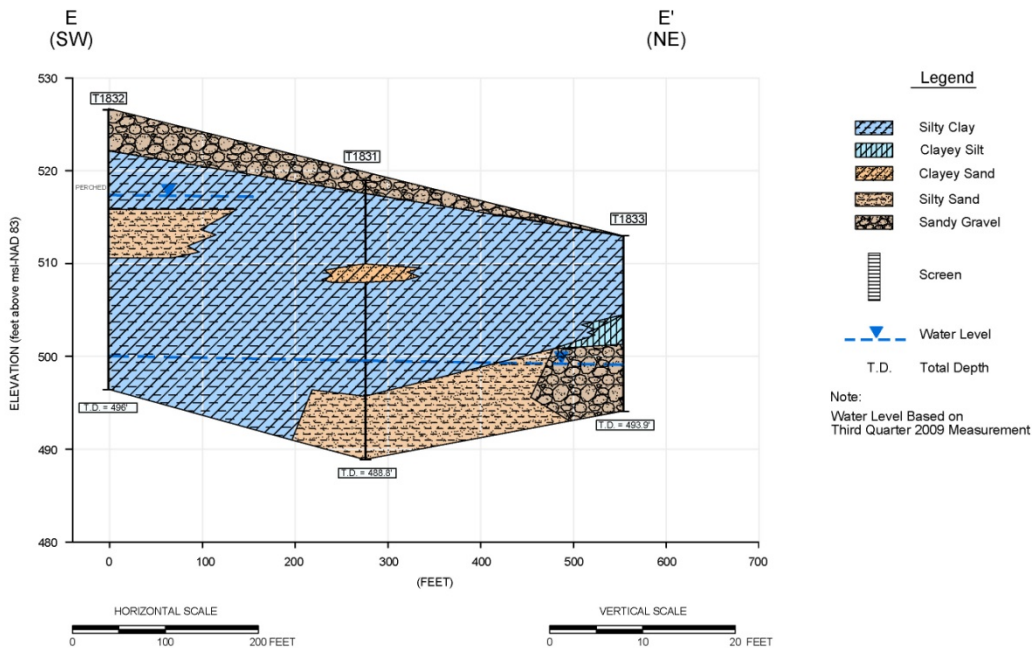


Figure 18 – 1831 Floodplain Source Area Cross Section E-E'

Based on the preliminary ISCO approach and the area-specific information summarized above, a total of 14 pilot injection wells will be installed for the Pilot-Scale Treatability Study.

4.3.3.1 Utility Clearance

Prior to initiation of subsurface field activities, a site reconnaissance will be completed to stake and clear the proposed investigation locations. After location staking, Evonik will be contacted to identify subsurface utilities located in investigation area.

4.3.3.2 Soil Boring/Monitor Well Installation

Soil borings required for injection well installation will be advanced with direct-push technology, a truck-mounted, hollow-stem auger drilling rig or sonic rig. Soil samples will be collected continuously from the ground surface to the total depth of the soil probe, estimated to be a maximum depth of 30 feet bgs.

Once the soil samples are aboveground, a field representative will describe the soils according to the USCS, equivalent to ASTM D2488. In addition, a portion of each soil sample will be placed into individual Ziploc bags and the headspace gas will be monitored with a PID. This field screening technique, along with visual and olfactory observations of the soil, will be utilized to select soil samples for chemical analyses from the saturated interval. It is anticipated that three soil samples (i.e., 10-11, 17-18, and 25-26 feet bgs) will be collected from three soil probes advanced to the north, hydraulically down-gradient of monitor well 1831. Documented observations of the soil samples will consist of sample depth, lithology, color, structure, staining, degree of sample saturation, and the presence or absence of hydrocarbon odors. An Indiana LPG will sign off on the geologic boring logs.

After reaching the soil boring target depth of 30 feet bgs, injection wells will be constructed by installing 20 feet of 2-inch diameter, Schedule 40, flush threaded PVC screen; and 2-inch diameter, Schedule 40, flush threaded PVC casing to extend the well to ground surface. Actual depth intervals may vary based on field conditions observed at the time of well installation.

Upon completion of well casing and screen installation, filter pack will be placed within the annular space between the injection well casing and screen and the hollow-stem augers to a

height of approximately two feet above the screened interval. Thereafter, approximately two feet of granular bentonite will be installed above the filter pack and a cement/bentonite grout will be installed from the bentonite seal to the base of the locking-cap assembly. The injection well will then be completed within flush-mounted well completions, slightly elevated from the surrounding ground surface.

The following information will be entered into the injection well construction log:

- Project name;
- Project location;
- Drilling subcontractor;
- Field representative;
- Well identification;
- Date installed;
- Completion materials and corresponding depths (bgs);
- Top-of-casing and ground level elevations; and,
- Surface completion.

After the cement and concrete are allowed to cure for approximately 24 hours, well development activities will commence. Development activities will continue until developed water is relatively free of suspended sediment and field pH, specific conductance, and temperature measurements are equilibrated. Upon well completion, an Indiana-licensed public land surveyor will be retained to establish top-of-casing elevation for the newly installed wells.

Following completion of the Pilot-Scale Treatability Study, pilot injection wells will be considered for plugging in accordance with 312 IAC 13-10-2. A final recommendation as to whether the injection wells will be plugged will be made in the Final Treatability Study Report.

4.3.3.3 Analytical Laboratory Testing

A portion of soil from each sample interval will be placed into laboratory provided sample containers and labeled with the following information: location, ID number, container number, depth (soil), date, time, and sampling personnel. This information will also be entered on a chain-of-custody form. Soil samples will be placed into a cooler and chilled to a temperature of approximately 4°C for shipment to a Heritage Environmental Services, LLC laboratory in Indianapolis, Indiana for analysis of VOCs by U.S. EPA Test Method 8260, SVOCs by U.S. EPA Test Method 8270, and metals by U.S. EPA Test Method 6010/7000.

4.3.3.4 Decontamination and Field Derived Waste Disposal

Drilling and sampling equipment will be decontaminated prior to the initiation of soil boring/well installation activities. Decontamination fluids and personal protective equipment generated during the field investigation will be stored on-site in drums and properly disposed at the completion of field activities and receipt of analytical results.

4.4 APPLICATION METHOD, DOSAGE, AND MONITORING

4.4.1 Application Method

The application method chosen for the Pilot-Scale Treatability Study is based on known subsurface conditions and vendor recommendations. The bioenhancement injection program will be conducted approximately ~~four~~twelve weeks after the completion of the oxidant injection program within each of the three source areas. Confirmation of the effectiveness of the oxidant and bioenhancement injection programs will be verified during injection and following the Pilot-Scale Treatability Study.

4.4.1.1 Main Plant Source Area

Application of oxidant will occur through the simultaneous injection across the entire screened interval for the three injection wells, matching the vertical saturated thickness of the water-bearing unit. Equipment used for performance of this activity will include the following:

- Mixing tanks (i.e., oxidant and bioenhancement chemical)
- Injection pump rated for 5 gallons per minute (gpm) @ 200 pounds per square inch (psi)
- Injection hosing and a pressure relief valve with a bypass to a “blow-down” tank
- Hosing between mixing tank/drum and pump
- Pressure gauges
- Power drill paint stirrer (3-inch diameter or smaller propeller tip)
- Plastic bucket lid puller tool/opener tool
- 5-amp sump pump (such as Little Giant) and hose
- Access to water or mobile water storage tank
- Access to electricity or electrical generator

4.4.1.2 1855 Source Area

Application of oxidant will occur through the simultaneous injection across the entire screened interval for the three injection wells, matching the vertical saturated thickness of the water-bearing unit. Equipment used for performance of this activity will include the following:

- Mixing tanks (i.e., oxidant and bioenhancement chemical)
- Injection pump rated for 5 gpm @ 200 psi
- Injection hosing and a pressure relief valve with a bypass to a “blow-down” tank
- Hosing between mixing tank/drum and pump
- Pressure gauges
- Power drill paint stirrer (3-inch diameter or smaller propeller tip)
- Plastic bucket lid puller tool/opener tool
- 5-amp sump pump (such as Little Giant) and hose
- Access to water or mobile water storage tank
- Access to electricity or electrical generator

4.4.1.3 1831 Floodplain Source Area

Application of oxidant will occur through the simultaneous injection across the entire screened interval for five, then four, then five injection wells, matching the vertical saturated thickness of the water-bearing unit. Equipment used for performance of this activity will include the following:

- Mixing tanks (i.e., oxidant and bioenhancement chemical)
- Injection Pump rated for 5 gpm @ 200 psi
- Injection hosing and a pressure relief valve with a bypass to a “blow-down” tank
- Hosing between mixing tank/drum and pump
- Pressure gauges
- Power drill paint stirrer (3-inch diameter or smaller propeller tip)
- Plastic bucket lid puller tool/opener tool
- 5-amp sump pump (such as Little Giant) and hose
- Access to water or mobile water storage tank
- Access to electricity or electrical generator

4.4.2 Application Dosage

~~The application dosage used in the Pilot Scale Treatability Study and monitoring results will help establish the optimum dosage for full-scale implementation. The application dosage data from the Bench Scale Treatability Study will be incorporated in the evaluation as well. The Pilot Scale Treatability Study application dosage for the source area and the down-gradient area will be evaluated with regard to the treatment efficiency versus the application dosage and destruction efficiency from the Bench Scale Treatability Study. Information regarding the ability to deliver the required amount of material to the treatment zone in each injection interval for the source area and down-gradient area will be based on field conditions.~~

A proposed Pilot-Scale application dosage for the chemical oxidant in each source area will be determined following the Bench-Scale Test, and proposed in the Technical Memorandum. This dosage will be determined based upon expected field conditions, COC concentrations within each Pilot Area, and the results of the Bench-Scale Test.

However, injection rates will have to be determined in the field during the Pilot-Scale Test at each location. Until that time, the ability to inject proposed volumes of material into the treatment zones will not be known.

Similar injection rates will likely be assumed for the bioenhancement product injection as what are achieved during the ISCO phase of the Pilot-Scale Test.

Data collected during both phases of the Pilot-Scale Test will be used to refine the dosages and injection rates to be used during the full-scale implementation.

4.4.2.1 Main Plant Source Area

Table 7 presents a summary of the information required to develop applicable application rates for the Main Plant Source Area. Information obtained from the Bench-Scale Treatability Study will be used to identify the oxidant and to estimate the quantity of oxidant and injection rate.

Table 7 - Main Plant Source Area Application Rate

Area of Treatment	15,000 square feet
Treatment Thickness	18 feet
Volume of Area	10,000 cubic yards
Estimated COC Mass in Treatment Area (Dissolved-Phase Only)	Benzene: 1,750 grams CB: 650 grams THF: 850 grams pCBT: 0 grams n,n-DEA: 72,000 grams Other: <u>6,150 grams</u> Total: 81,400 grams
Estimated Chemical Oxidant Dosage	To Be Determined During Bench-Scale
Estimated Injection Rate	To Be Determined in the field
Oxidant Flushing After Placement	Approximately 50 gallons of potable water will be used to flush the injection well and help distribute the injected oxidant.
Extraction Well Startup and Monitoring	Extract from 1880, and monitor at monitor wells 1818, 1908, 1814, 1808, and 1880 (after operation of this well ceases)
Bioenhancement Injection Timing	Approximately four <u>twelve</u> weeks following the final chemical oxidant injection
Estimated Bioenhancement Dosage	To Be Determined Following Bench-Scale, dependant upon chemical oxidant dosage, and monitoring conducted during the oxidant phase of the pilot-scale testing.
Estimated Injection Rate	To Be Determined in the field

Start pumping extraction well 1880 five days prior to starting injection. Continue pumping while performing injection activities, until field monitoring indicates a chemical response at the extraction well, then the extraction well will be turned off. Distribution of the oxidant will be tracked through field monitoring of pH, dissolved oxygen (DO), and oxygen reduction potential (ORP).

4.4.2.2 1855 Source Area

Table 8 presents a summary of the information required to develop applicable application rates for the 1855 Source Area. Information obtained from the Bench-Scale Treatability Study will be used to identify the oxidant and to estimate the quantity of oxidant and injection rate.

Table 8 - 1855 Source Area Application Rate

Area of Treatment	600 square feet
Treatment Thickness	1.5 feet
Volume of Area	33 cubic yards
Estimated COC Mass in Treatment Area (Dissolved-Phase Only)	Benzene: 0 grams CB: 0 grams THF: 0 grams pCBT: 5 grams n,n-DEA: 0 grams Other: <u>0 grams</u> Total: 5 grams
Estimated Oxidant Dosage	To Be Determined During Bench-Scale
Estimated Injection Rate	To Be Determined in the field
Oxidant Flushing After Placement	Approximately 10 gallons of potable water will be used to flush the injection well and help distribute the injected oxidant.
Bioenhancement Injection Timing	Approximately four <u>twelve</u> weeks following the final chemical oxidant injection
Estimated Bioenhancement Dosage	To Be Determined Following Bench-Scale, dependant upon chemical oxidant dosage, and monitoring conducted during the oxidant phase of the pilot-scale testing.
Estimated Injection Rate	To Be Determined in the field

4.4.2.3 1831 Floodplain Source Area

Table 9 presents a summary of the information required to develop applicable application rates for the 1831 Floodplain Source Area. Information obtained from the Bench-Scale Treatability Study will be used to identify the oxidant and to estimate the quantity of oxidant and injection rate.

Table 9 - 1831 Floodplain Source Area Application Rate

Area of Treatment	5,000 square feet
Treatment Thickness	20 feet
Volume of Area	3,700 cubic yards
Estimated COC Mass in Treatment Area (Dissolved-Phase Only)	Benzene: 280 grams CB: 190 grams THF: 2,940 grams pCBT: 0 grams n,n-DEA: 0 grams Other: <u>3,170 grams</u> Total: 6,580 grams
Estimated Oxidant Dosage	To Be Determined During Bench-Scale
Estimated Injection Rate	To Be Determined in the field
Oxidant Flushing After Placement	Approximately 50 gallons of potable water will be used to flush the injection well and help distribute the injected oxidant.
Bioenhancement Injection Timing	Approximately four - <u>twelve</u> weeks following the final chemical oxidant injection
Estimated Bioenhancement Dosage	To Be Determined Following Bench-Scale, dependant upon chemical oxidant dosage, and monitoring conducted during the oxidant phase of the pilot-scale testing.
Estimated Injection Rate	To Be Determined in the field (Note that only five southern-most injection wells will be utilized)

4.4.3 Monitoring and Sample Collection/Analysis

Monitoring data collected during the Pilot-Scale Treatability Study can provide insight for the selection of monitoring parameters in the full-scale implementation. Parameters that exhibit little or no impact due to the treatment technology may be considered for deletion in the full-scale phase. Conversely, if additional monitoring parameters are deemed to be necessary during the Pilot-Scale Treatability Study to provide additional clarity on the effectiveness of treatment, they would be included in the monitoring efforts planned for the full-scale implementation.

4.4.3.1 Main Plant Source Area

Typical field instrument and groundwater sampling will be performed at monitor wells 1818, 1908, 1814, 1808, and 1880. Monitoring will continue for a period of three months following the bioenhancement injection (a total of ~~four~~six months after completing the oxidant injection). Table 10 provides a detailed monitoring schedule during and after the injection events.

Table 10 - Main Plant Source Area Pilot-Scale Monitoring Schedule

Event	Monitoring	Analysis
1	Prior to Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, and aniline
	During Injection	Temperature, pH, specific conductance, DO, ORP
2	One Week After Completing Oxidant Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, manganese, aniline, chlorides, and fluoride
3	One Month After Completing Oxidant Injection and Prior to Bioenhancement Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, aniline, chlorides, and fluoride.
<u>4</u>	<u>Two Months After Completing Oxidant Injection</u>	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, aniline, chlorides, and fluoride.</u>
<u>5</u>	<u>Three Months After Completing Oxidant Injection and Prior to Bioenhancement Injection</u>	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, TOC and aniline</u>
<u>46</u>	One Month After Bioenhancement Injection	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, TOC and aniline</u> Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, aniline, chlorides, and fluoride.
<u>57</u>	Two Months After Bioenhancement Injection	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, TOC and aniline</u> Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, aniline, chlorides, and fluoride.
<u>68</u>	Three Months After Bioenhancement Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron,

		manganese, methane, nitrate, sulfate, fluoride, <u>TOC</u> and aniline
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Notes:

- Groundwater samples will be collected in accordance with the Groundwater QAPP Revision 3, dated May 2010.
- Field measurements of temperature, pH, specific conductance, DO, and ORP will be made immediately before injection starts and will continue on a frequent basis (to be determined in the field) throughout the period that chemical injection occurs.
- Use of bromide or other tracer may not be necessary based on the rapid chemical response typically associated with the proposed chemical oxidants and observed in pH, DO, and ORP. However, the usefulness of these field measurement parameters is highly dependent upon the particular chemical oxidant. Therefore, use of tracers will be re-evaluated following the bench-scale treatability study and final selection of the pilot-scale chemical oxidant.
- TICs reported by the laboratory will be documented to identify potential breakdown products.

In addition, soil samples are anticipated to be collected within three months after the final injection event from the locations shown in orange on Figure 19 (replicating the approximate locations and intervals tested prior to initiation of the Pilot-Scale Treatability Study) – located north of monitor well 1814 and the second location will be located southeast of monitor well 1815. The sample collected from the location southeast of 1815 is more of a control location and may not be collected if definitive geochemical change in groundwater samples collected from nearby monitor wells does not indicate that oxidant reached this area.

<u>Well ID</u>	<u>Screened Interval (ft. bgs)</u>	<u>DTW (ft. bgs)</u>	<u>Saturated Soil Type</u>	<u>Proposed Soil Sample Interval</u>
1814	55 – 67	61	Fine Sand with Gravel	62 – 67
1815	66 – 96	64	Gravelly Sand	65 – 70

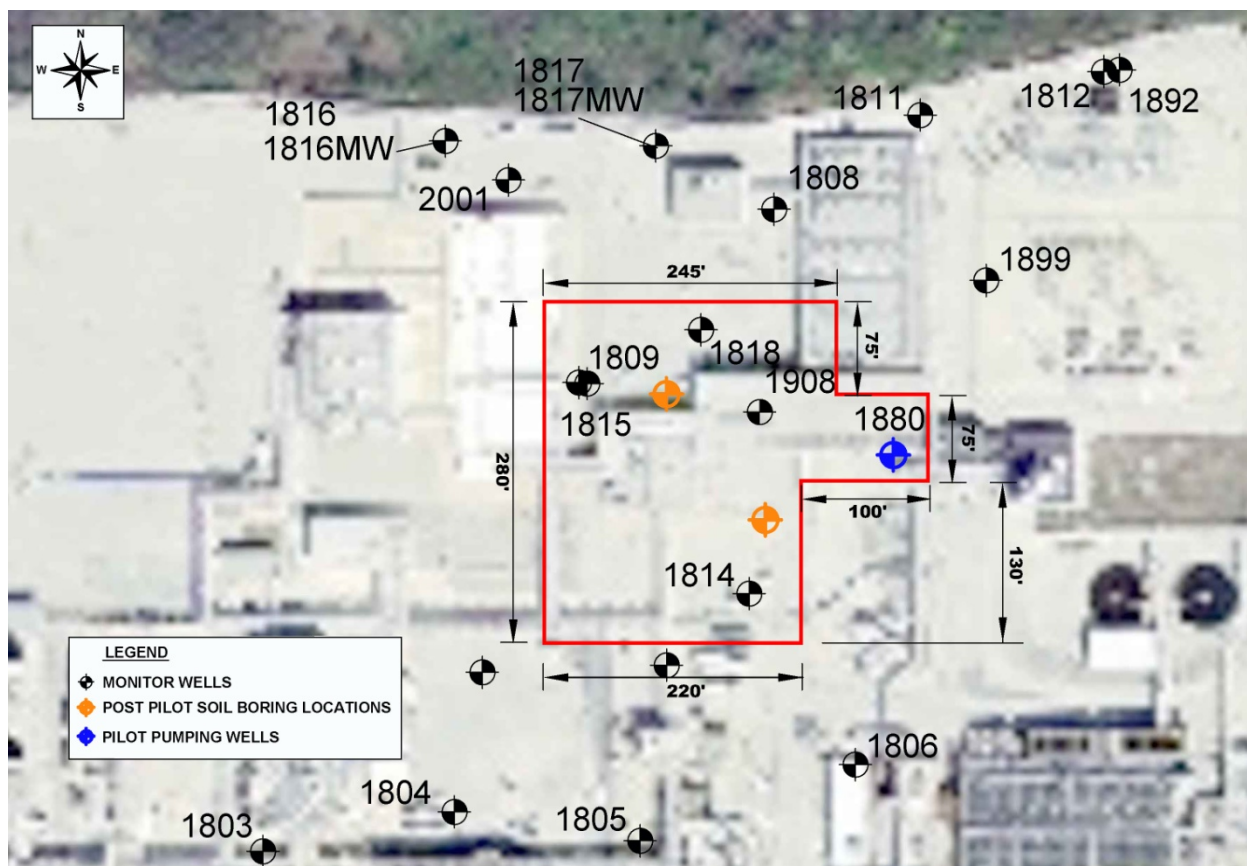


Figure 19 – Main Plant Source Area Post Pilot-Scale Sample Locations

This sampling will be performed to evaluate ISCO and enhanced bioremediation effectiveness on the saturated soils and subsurface conditions related to implementation of a full-scale treatment program.

4.4.3.2 1855 Source Area

In order to better assess the pilot-scale test, two additional monitor wells will be installed in the 1855 Source Area, one approximately 30 feet down-gradient of the pilot injection locations and one approximately 60 feet down-gradient of the pilot injection locations (see Figure 20). Typical field instrument and groundwater sampling will be performed at monitor well 2011 and the two newly installed monitor wells (NMW-1 and NMW-2). Monitoring will continue for a period of three months following the bioenhancement injection (a total of ~~four~~six months after completing

the oxidant injection). Table 11 provides a detailed monitoring schedule during and after the injection events.

Table 11 - 1855 Source Area Pilot-Scale Monitoring Schedule

Event	Monitoring	Analysis
1	Prior to Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, and fluoride
	During Injection	Temperature, pH, specific conductance, DO, ORP
2	One Week After Completing Oxidant Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, metals, manganese, fluoride, and chlorides
3	One Month After Completing Oxidant Injection and Prior to Bioenhancement Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, fluoride, and chlorides
<u>4</u>	<u>Two Months After Completing Oxidant Injection</u>	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, fluoride, and chlorides</u>
<u>5</u>	<u>Three Months After Completing Oxidant Injection and Prior to Bioenhancement Injection</u>	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, and TOC</u>
<u>46</u>	One Month After Bioenhancement Injection	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, and TOC</u> Temperature, pH, specific conductance, DO, ORP, VOCs, fluoride, and chlorides
<u>57</u>	Two Months After Bioenhancement Injection	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, and TOC</u> Temperature, pH, specific conductance, DO, ORP, VOCs, fluoride, and chlorides
<u>68</u>	Three Months After Bioenhancement Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, and fluoride, <u>and TOC</u>

Notes:

- Groundwater samples will be collected in accordance with the Groundwater QAPP Revision 3, dated May 2010.
- Field measurements of temperature, pH, specific conductance, DO, and ORP will be made immediately before injection starts and will continue on a frequent basis (to be determined in the field) throughout the period that chemical injection occurs.
- Use of bromide or other tracer may not be necessary based on the rapid chemical response typically associated with the proposed chemical oxidants and observed in pH, DO, and ORP. However, the usefulness of these field measurement parameters is highly dependent upon the particular chemical oxidant. Therefore, use of tracers will be re-evaluated following the bench-scale treatability study and final selection of the pilot-scale chemical oxidant.
- TICs reported by the laboratory will be documented to identify potential breakdown products.

In addition, soil samples will be collected within three months after the final injection event from the following locations shown in orange on Figure 20 (replicating the approximate locations and intervals tested prior to initiation of the Pilot-Scale Treatability Study).

<u>Well ID</u>	<u>Screened Interval (ft. bgs)</u>	<u>DTW (ft. bgs)</u>	<u>Saturated Soil Type</u>	<u>Proposed Soil Sample Interval</u>
2011	63 – 68	65	Sand and Gravel	68 – 70



Figure 20 – 1855 Source Area Post Pilot-Scale Sample Locations

This sampling will be performed to evaluate ISCO and enhanced bioremediation effectiveness on the saturated soils and subsurface conditions related to implementation of a full-scale treatment program.

4.4.3.3 1831 Floodplain Source Area

Typical field instrument and groundwater sampling will be performed at monitor wells 1831, 1833, 1834, 1832, and 1876. Monitoring will continue for a period of three months following the bioenhancement injection (a total of ~~four~~six months after completing the oxidant injection). Table 12 provides a detailed monitoring schedule during and after the injection events.

Table 12 - 1831 Floodplain Source Area Pilot-Scale Monitoring Schedule

Sample Event	Monitoring	Analysis
1	Prior to Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, and aniline
	During Injection	Temperature, pH, specific conductance, DO, ORP
2	One Week After Completing Oxidant Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, manganese, aniline, chlorides, and fluoride
3	One Month After Completing Oxidant Injection and Prior to Bioenhancement Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, aniline, chlorides, and fluoride
<u>4</u>	<u>Two Months After Completing Oxidant Injection</u>	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, aniline, chlorides, and fluoride</u>
<u>5</u>	<u>Three Months After Completing Oxidant Injection and Prior to Bioenhancement Injection</u>	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, TOC, and aniline</u>
<u>46</u>	One Month After Bioenhancement Injection	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, TOC, and aniline</u> Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, aniline, chlorides, and fluoride

<u>57</u>	Two Months After Bioenhancement Injection	<u>Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, TOC, and aniline</u> Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, aniline, chlorides, and fluoride
<u>68</u>	Three Months After Bioenhancement Injection	Temperature, pH, specific conductance, DO, ORP, VOCs, SVOCs, metals, alkalinity, ammonia, carbon dioxide, chlorides, ferrous and dissolved iron, manganese, methane, nitrate, sulfate, fluoride, <u>TOC</u> , and aniline

Notes:

- Groundwater samples will be collected in accordance with the Groundwater QAPP Revision 3, dated May 2010.
- Field measurements of temperature, pH, specific conductance, DO, and ORP will be made immediately before injection starts and will continue on a frequent basis (to be determined in the field) throughout the period that chemical injection occurs.
- Use of bromide or other tracer may not be necessary based on the rapid chemical response typically associated with the proposed chemical oxidants and observed in pH, DO, and ORP. However, the usefulness of these field measurement parameters is highly dependent upon the particular chemical oxidant. Therefore, use of tracers will be re-evaluated following the bench-scale treatability study and final selection of the pilot-scale chemical oxidant.
- TICs reported by the laboratory will be documented to identify potential breakdown products.

In addition, soil samples will be collected within three months after the final injection event from locations replicating the approximate locations and intervals tested prior to initiation of the Pilot-Scale Treatability Study (within the area depicted in Figure 21).

<u>Well ID</u>	<u>Screened Interval (ft. bgs)</u>	<u>DTW (ft. bgs)</u>	<u>Saturated Soil Type</u>	<u>Proposed Soil Sample Interval</u>
1831	23 – 28	8.75	Clayey Sand	9 – 14
			Silty Clay	16 – 21
			Silty Sand	24 – 29

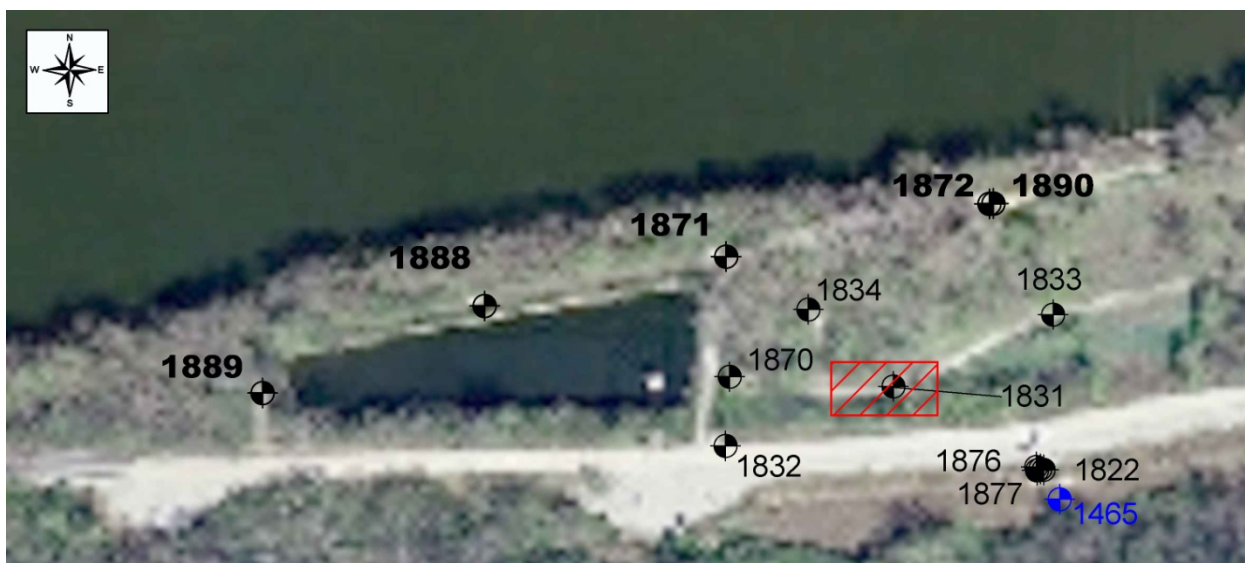


Figure 21 – 1831 Floodplain Source Area Post Pilot-Scale Sample Locations

This sampling will be performed to evaluate ISCO and enhanced bioremediation effectiveness on the saturated soils and subsurface conditions after completion of treatment.

4.4.3.4 Field Contingencies

The proposed Pilot-Scale Treatability Study injection locations, application rate, and field procedures may be revised based on field observations. Any such deviations from the Work Plan will be documented and the reasons for the deviation explained in the Pilot-Scale Treatability Study Report. Potential deviations and the general responses are provided below:

- **Underground utility identification.** If underground utilities are identified in a location where an injection point is planned, the location of the injection point will be moved to the nearest location to the proposed injection point that is at least 10 feet away from identified underground utilities.
- **Lack of response observed at monitor wells.** If no chemical response is recorded in the field at nearby monitor wells, additional chemical will be injected. Up to 150% of the original injection volume will be injected at the nearest injection location to the unresponsive monitor well. If no chemical response is observed after this additional injection quantity, injections will cease and monitoring will be continued. Analysis for metals will continue until after a chemical response is observed at the monitor well.

- **Loss of chemical injection control.** If injection chemical is observed at the surface emanating from monitor wells or other locations, chemical injection activities will cease to allow assessment of underground flow paths. Similarly, if any ground heaving, excessive injection back-pressure, or other evidence of a loss of chemical injection control is observed, chemical injection activities will cease to allow assessment of the cause of such loss of control. After a field assessment is made, injection activities would re-commence if appropriate.

4.5 REPORTING

Upon completion of the Pilot-Scale Treatability Study, a comprehensive report will be prepared that will present the data, discuss trends and anomalies, and present the findings regarding the overall viability of the remedial approach.

5.0 SCHEDULE

Table 13 provides a tentative schedule for performance of the Bench-Scale and Pilot-Scale Treatability Study at the Site. Implementation of field activities will be based on receipt of regulatory approval and seasonal weather conditions.

Table 13 - Bench-Scale and Pilot-Scale Treatability Study Schedule

Step	Activity	Duration
1	Submittal of Bench-Scale and Pilot-Scale Treatability Study Work Plan	April 2012
2	U.S. EPA Approval of Bench-Scale and Pilot-Scale Treatability Work Plan	
3	Supplemental Soil Characterization (1855)	30 Days
4	Bench-Scale Sample Collection (soil and groundwater) and Well Installation (concurrent with Step 3)	5 Days
5	Bench-Scale Treatability Study and Laboratory Testing	45 Days + 14 Days
6	Bench-Scale Treatability Study Technical Memorandum	60 Days
7	U.S. EPA Approval of Bench-Scale Treatability Study Technical Memorandum	
8	Pilot-Scale Treatability Study – Well Installation, Sampling, and Laboratory Testing	60 Days
9	Pilot-Scale Treatability Study – Chemical oxidant injection based on original projected injection quantity: Main Plant Source Area 1855 Source Area 1831 Floodplain Source Area	3-5 Days 1-2 Days 3-5 Days
10	Pilot-Scale Treatability Study – Bioenhancement injection 28-days <u>12 weeks</u> after chemical oxidant injection Main Plant Source Area 1855 Source Area 1831 Floodplain Source Area	3-5 Days 1-2 Days 1-2 Days
11	Pilot-Scale Treatability Study – Monitoring (concurrent with Steps 9 and 10)	120-180 Days
12	Pilot-Scale Treatability Study – Post Treatment Soil Sampling and Laboratory Testing	21 Days
13	Reporting	60 days after receipt of final results
14	U.S. EPA Approval of Bench-Scale and Pilot-Scale Report	